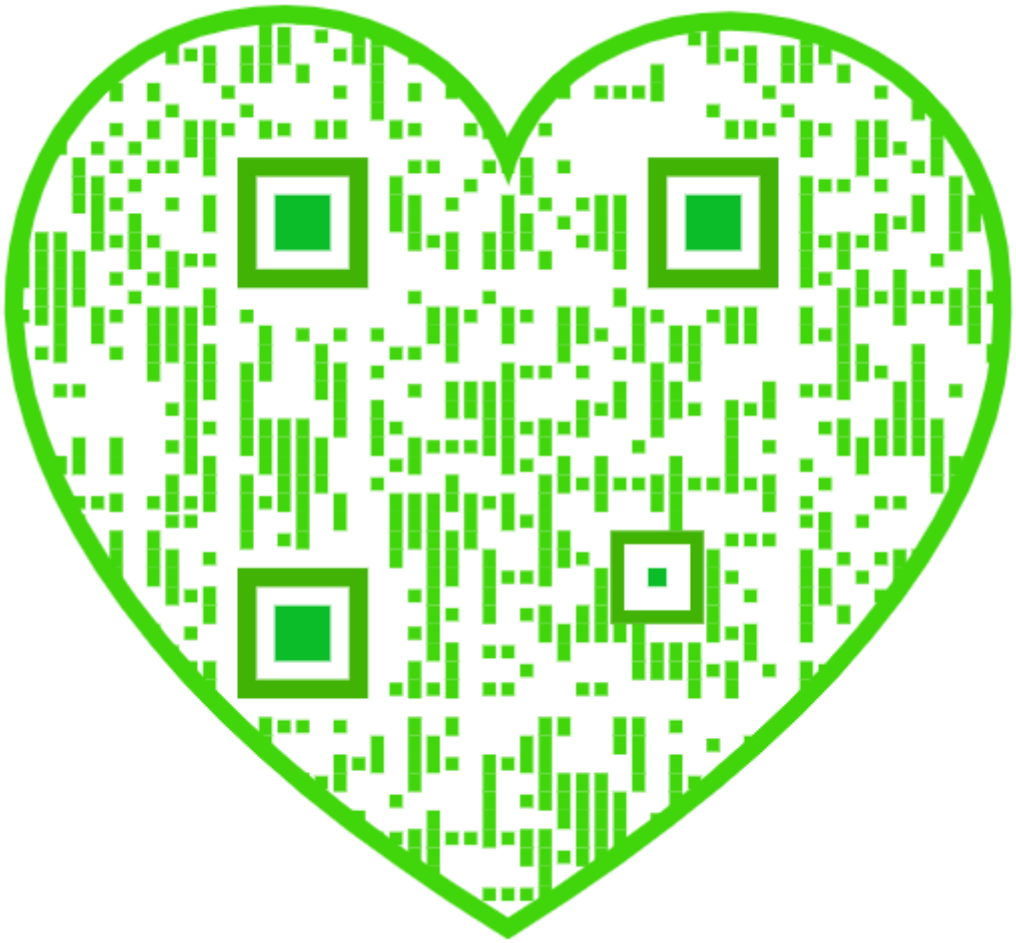
THE NEW METAL WORKER PATTERN BOOK



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THE NEW METAL WORKER PATTERN BOOK

A TREATISE ON THE PRINCIPLES AND PRACTICE OF PATTERN CUTTING AS APPLIED TO SHEET METAL WORK.

BY GEO. W. KITTREDGE.

NEW YORK:
DAVID WILLIAMS COMPANY, 232-238 WILLIAM STREET,
1901.

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Introduction.

FOR the benefit of those who may contemplate making use of this work, wholly or in part, it is well to lay before them at the outset a general statement of the plan upon which it is written, together with some advice for the use and study of the same, which may not properly belong under any of the several headings comprising the subject matter. A glance at the table of contents immediately preceding will give at once a clear idea of its scope and arrangement. From this it will be seen that the first five chapters are theoretical or educational in their nature, while the last chapter is devoted to practical work; and further, that the book does not presume upon any previous technical knowledge upon the part of the beginner, but aims to place before him in the preliminary chapters all that is necessary to a thorough understanding of the work performed in the last chapter, which constitutes the bulk of the book.

A very important feature of the work is the classification of the problems. The forms for which patterns may be required are divided, according to the methods employed in developing their surfaces, into three classes, and the problems relating to each are arranged in three corresponding sections of the last chapter, thus bringing near together those in which principles and methods are alike. In Chapter V (Principles of Pattern Cutting) this classification is defined and the principles governing each class are explained and illustrated under three sub-headings of the chapter. The third subdivision treats of the method of developing the surfaces of irregular forms by *Triangulation*, a subject not heretofore systematically treated in any work on pattern cutting.

A chapter on drawing (Chapter III) has been prepared for the benefit of the pattern cutter especially interested in cornice work, and though he may not intend to become a finished architectural draftsman, this chapter will render him valuable assistance in reading the original drawings received from architects, from which he is required in many cases to make new drawings adapted to his own peculiar wants.

The New Metal Worker Pattern Book, besides being a systematic treatise on the principles of pattern cutting, is also valuable as a reference book of pattern problems and as a fund of information on the subject treated, to be drawn from at convenience, and is so written that each problem, or chapter of descriptive matter, can be read independently of the others; so that the student whose time is limited can turn to any portion of the work the title of which promises the information sought, without feeling that he must read all that precedes it. The relative importance of the chapters depends, of course, upon the individual reader, and will be determined by what he considers his weakest points. However, it is advisable in the study of all works of a scientific nature to begin at the beginning and take everything in its course. If, therefore, the study of this work can be continued progressively from the first, much advantage will be gained.

The statement of each problem in prominent type appears at the head of the demonstration,

and every problem is numbered, by which arrangement the problems are well separated from each other and easily found.

While each demonstration is considered complete in itself, some are necessarily carried farther into detail than others, and references are made from one problem to another, pointing out similarity of principle, where such comparison would be advantageous to one who is looking for principles rather than for individual solutions.

In preparing the diagrams used to illustrate the solutions of the problems, forms have been chosen which are as simple in outline as the case will admit, upon the supposition that the reader will be able to make the application of the method described in connection with the same to his own especial case, which may embody more complicated forms. It must also be noted that, owing to the small scale to which the drawings in this work are necessarily made, extreme accuracy in the operations there performed is impossible. In many instances the length of the spaces used in dividing the profiles is much too great in proportion to the amount of curvature to insure accuracy. Therefore if apparent errors in measurements or results are found, they must not be considered the fault of the system taught. If such errors are discovered the student is recommended to reconstruct the drawing upon his own drawing board in accordance with the demonstration given and to a scale sufficiently large to insure accurate results, before passing judgment.

In the preparation of this book, the former Metal Worker Pattern Book has been made the basis, to a certain extent, of the new work.* Such problems or portions of the former work as were found satisfactory have been assigned to their proper places in the new work without change. In the case of most of the problems, however, the demonstrations have been revised and the drawings accompanying them have been amended or corrected in accordance with the text, and in many cases entire new drawings have been made. To these have been added a large number of new problems based upon inquiries and solutions that have appeared in the columns of *The Metal Worker* since the former work was published. Much new explanatory matter not in the former work has also been added in the preliminary chapters, prominent among which are Chapter III, and the principles of Triangulation in Chapter V.

Especial care has been taken in the composition of the book to have each engraving and the text referring to it arranged, as far as possible, on the same page or upon facing pages, so as to obviate the necessity of turning the leaf in making references.

A great advantage is gained over the former work by the classification and numbering of the problems, which, in connection with the table of contents, renders any desired subject or problem easily found.

In regard to the system of reference letters employed in the drawings, it should be said that the same letter has been used so far as possible to represent any given point in the several views or positions in which it may occur, the superior figure or exponent being changed in each view. To fully comprehend this the reader must carry in mind the concrete idea of the form under consideration, just as though he held in his hand a perfect completed model of the same, which he turned this way or that to obtain the several views given. Any point, therefore, which might on the model be marked by a letter A, would be designated in one of the views as A, while in other views or places where it might appear it would be designated as A^1, A^2, etc., or as A′, A″, etc. In the

*** Publisher's Note.—The author of this book, George W. Kittredge, prepared the drawings and outlined the demonstrations of all but a few of the less important problems in The Metal Worker Pattern Book, which was published in 1881, and also prepared portions of the introductory chapters of that work.**

solution of problems by triangulation, dotted lines are alternated with solid lines, as lines of measurement, merely for the sake of distinction and to facilitate the work.

Occasions arise in the experience of every pattern cutter wherein some portion of the work before him, of relatively small importance, is so situated that the development of its pattern by a strictly accurate method would involve more labor and time than would be justified by the value of the part wanted. It is the purpose of this work to teach the principles of pattern cutting, leaving the decision of such questions to the individual. Nevertheless, if one is thoroughly conversant with pattern cutting methods and familiar with pattern shapes it may be possible in such cases to obtain accurately the principal points of a required pattern and to complete the same by the eye with sufficient accuracy for all practical purposes.

As intimated above, some of the demonstrations are necessarily made more explicit than others. In the longer demonstrations and those occurring near the ends of the Sections, less important details of the work are sometimes omitted and certain parts of the operation are only hinted at or are described in a general way, upon the supposition that the simpler problems in which the demonstrations are carried further into detail would naturally be studied first.

Although the principles of pattern cutting here set forth may at times be regarded as somewhat intricate, it is believed that any one possessed of a fair degree of intelligence and application can easily master them.

Notwithstanding the great care which has been used in the preparation of this work, it is possible that errors may have found their way into its columns. Should errors be discovered by any of its readers, information of such will be gladly received.

CHAPTER I.

Terms and Definitions.

Pattern cutting as applied to sheet-metal work, by its very nature, involves the application of geometrical principles. Any treatise on descriptive geometry presents in a general way all the principles that enter into the science of pattern cutting. To those who have had the advantages of a mathematical education these principles are well known and by such their application is easily made. For the benefit of those, however, who have not had such advantages, this work purposes to make specific application of those principles in a way to be readily understood by the mechanic. While throughout the work the use of an unnecessary number of technical terms and words not in common use among mechanics will be carefully avoided, it must be here noted that *precise language* in describing all geometrical figures and operations becomes a necessity, and therefore compels the employment of some terms not in the every day vocabulary of the workshop, which it is proper to define and explain at the outset. As the language of the workshop is usually far from accurate and varies with the locality, every student of this book will find it greatly to his advantage to give careful attention to this and the other introductory chapters for the purpose of increasing and improving his vocabulary, and of enabling him to more readily comprehend the demonstrations in the pages following. The list of terms herein defined has not been restricted to the barest requirements of the book, but has been made to include nearly all the terms belonging to plain geometry, and such architectural terms as are usually met with in problems relating to cornice work. The terms are arranged first logically, in classes, after which follows an alphabetical list by which any definition can be readily found.

1. **Geometry** is that branch of mathematics which treats of the relations, properties and measurements of lines, angles, surfaces and solids.

2. **Sheet-Metal Pattern Cutting** is founded upon those principles of geometry which relate to the surfaces of solids, and may be more accurately described as the *development of surfaces*, under which name its principles are now being taught to a great extent in schools of practical instruction. Articles made from sheet metal are hollow, being only shells, and must, therefore, be considered in the process of pattern cutting as though they were the coverings or casings stripped from solids of the same shape.

3. A **Point** is that which has place or position without magnitude, as the intersection of two lines or the center of a circle; it is usually represented to the eye by a small dot.

LINES.

4. A **Line** is that which has length merely, and may be straight or curved.

5. A **Straight Line,** or, as it is sometimes called, a *right line*, is the shortest line that can be drawn between two given points. Straight lines are generally designated by letters or figures at their extremities, as A B, Fig. 1.

6. A **Curved Line** is one which changes its direction at every point, or one of which no portion, however small, is straight. It is therefore longer than a straight line connecting the same points. Curved lines

Fig. 1.—A Straight Line.

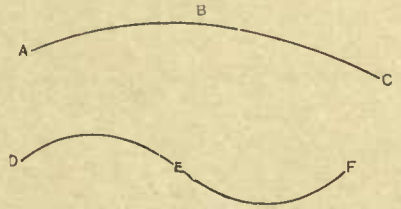


Fig. 2.—Curved Lines.

are designated by letters or figures at their extremities and at intermediate points, as A B C or D E F, Fig. 2.

7. **Parallel Lines** are those which have no inclination to each other, being everywhere equidistant. A B and A' B' in Fig. 3 are parallel straight lines, and

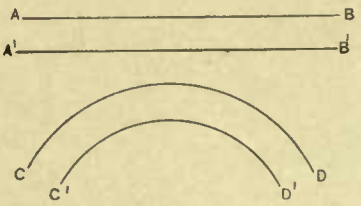


Fig. 3.—Parallel Lines.

can never meet though produced to infinity. C D and C' D' are parallel curved lines, being arcs of circles which have a common center.

8. **Horizontal Lines** are lines parallel to the horizon, or level. A Horizontal Line in a drawing is indicated by a line drawn from left to right across the paper, as A B in Fig. 4.

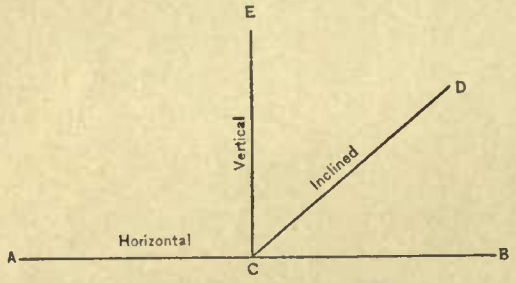


Fig. 4.—Names of Lines by Direction.

9. **Vertical Lines** are lines parallel to a plumb line suspended freely in a still atmosphere. A Vertical Line in a drawing is represented by a line drawn up and down the paper, or at right angles to a horizontal line, as E C in Fig. 4.

10. **Inclined or Oblique Lines** occupy an intermediate between horizontal and vertical lines, as C D,

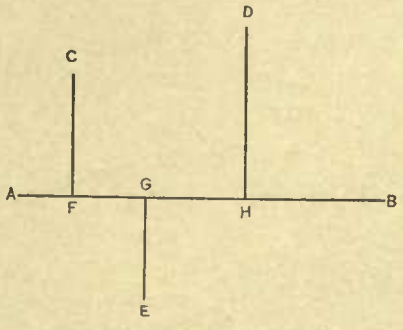


Fig. 5.—Perpendicular Lines.

Fig. 4. Two lines which converge toward each other and which, if produced, would meet or intersect, are said to incline to each other.

11. **Perpendicular Lines.**—Lines are perpendicular to each other when the angles on either side of the point of meeting are equal. Vertical and horizontal lines are always perpendicular to each other, but perpendicular lines are not always vertical and horizontal, but may be at any inclination to the horizon, provided that the angles on either side of the point of intersection are equal. In Fig. 5, C F, D H and E G are said to be perpendicular to A B. Also in Fig. 6,

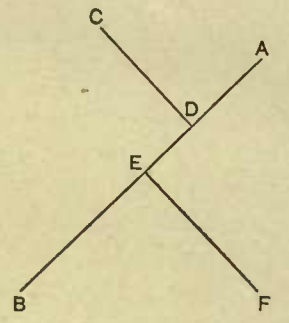


Fig. 6.—Perpendicular Lines.

C D and E F are perpendicular to A B. Lines perpendicular to the same line are parallel to each other, as C F and D H, Fig. 5, which are perpendicular to A B.

12. An **Angle** is the opening between two straight lines which meet one another. An angle is commonly designated by three letters, the letter designating the point in which the straight lines containing the angle

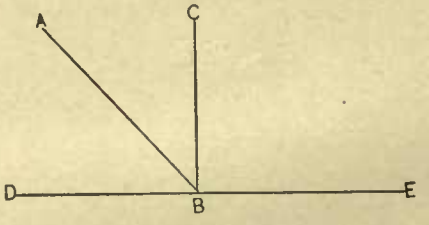


Fig. 7.—Angles.

meet being between the other two letters, as the angle E C D, Fig. 4.

13. A **Right Angle.**—When a straight line meets another straight line so as to make the adjacent angles equal to each other, each angle is a right angle, and the straight lines are said to be perpendicular to each other. (See C B E or C B D, Fig. 7.)

14. An **Acute Angle** is an angle less than a right angle, as A B D or A B C, Fig. 7.

15. An **Obtuse Angle** is an angle greater than a right angle, as A B E, Fig. 7.

STRAIGHT SIDED FIGURES.

16. A **Surface** is that which has length and breadth without thickness.

17. A **Plane** is a surface such that if any two of its points be joined by a straight line, such line will be wholly in the surface. Every surface which is not a plane surface, or composed of plane surfaces, is a *curved surface.*

18. A **Single Curved Surface** is one in which only certain points may be joined by straight lines which shall lie wholly in its surface. The rounded surface of a cylinder or cone is a single curved surface.

19. A **Double Curved Surface** is one in which no two points can be joined by a straight line lying wholly in its surface. The surface of a sphere, for example, is a double curved surface.

20. A **Plane Figure** is a portion of a plane terminated on all sides by lines either straight or curved.

21. A **Rectilinear Figure** is a surface bounded by straight lines. (See Figs. 8, 16, 21, etc.)

22. **Polygon** is the general name applied to all rectilinear figures, but is commonly applied to those having more than four sides. A *regular polygon* is one in which the sides are equal.

23. A **Triangle** is a flat surface bounded by three straight lines. (Figs. 8, 9, 10, 11, 13, etc.)

24. An **Equilateral Triangle** is one in which the three sides are equal. (Fig. 8.)

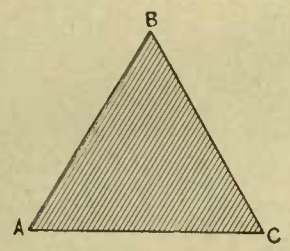


Fig. 8.—An Equilateral Triangle.

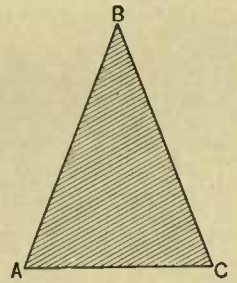


Fig. 9.—An Isosceles Triangle.

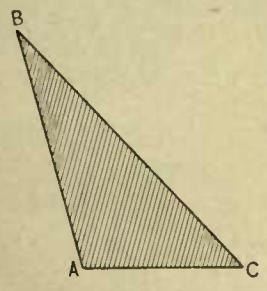


Fig. 10.—A Scalene Triangle.

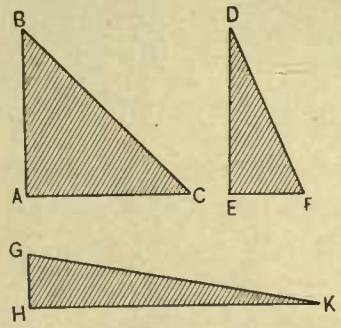


Fig. 11.—Right-Angled Triangles.

25. An **Isosceles Triangle** is one in which two of the sides are equal. (Fig. 9.)

26. A **Scalene Triangle** is one in which the three sides are of different lengths. (Fig. 10.)

27. A **Right-Angled Triangle** is one in which one of the angles is a right angle. (Fig. 11.)

28. An **Acute-Angled Triangle** is one which has its three angles acute. (Fig. 12.)

29. An **Obtuse-Angled Triangle** is one which has an obtuse angle. (Fig 13.)

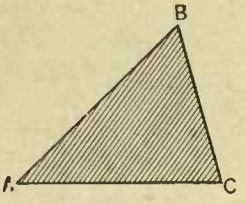


Fig. 12.—An Acute-Angled Triangle.

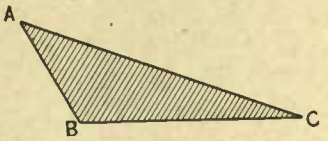


Fig. 13.—An Obtuse-Angled Triangle.

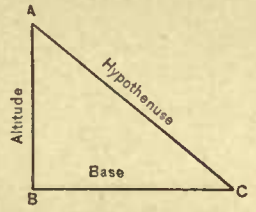


Fig. 14.—Names of the Sides of a Right-Angled Triangle.

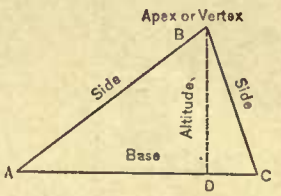


Fig. 15.—Names of the Parts of a Triangle.

30. A **Hypothenuse** is the longest side in a right-angled triangle, or the side opposite the right angle. A C, Fig. 14.

31. The **Apex** of a triangle is its upper extremity, as B, Fig. 15. It is also called vertex.

32. The **Base** of a triangle is the line at the bottom. B C and A C, Figs. 14 and 15.

33. The **Sides** of a triangle are the including lines. A C, A B and B C, Figs. 14 and 15.

34. The **Vertex** is the point in any figure opposite to and furthest from the base. The vertex of an angle is the point in which the sides of the angle meet. B, Fig. 15.

35. The **Altitude** of a triangle is the length of a perpendicular let fall from its vertex to its base, as B D, Fig. 15,

36. A **Quadrilateral** figure is a surface bounded by four straight lines. There are three kinds of Quadri-

laterals: The Trapezium, the Trapezoid and the Parallelogram.

37. The **Trapezium** has no two of its sides parallel. (Fig. 16.)

38. The **Trapezoid** has only two of its sides parallel. (Fig. 17.)

39. The **Parallelogram** has its opposite sides parallel. There are four varieties of parallelograms: The Rhomboid, the Rhombus, the Rectangle and the Square.

46. A **Heptagon** is a plane figure of seven sides. (Fig. 24.)

47. An **Octagon** is a plane figure of eight sides. (Fig. 25.)

48. A **Decagon** is a plane figure of ten sides. (Fig. 26.)

49. A **Dodecagon** is a plane figure of twelve sides. (Fig. 27.)

50. The **Perimeter** is the line or lines bounding any figure, as A B C D E, Fig. 22.

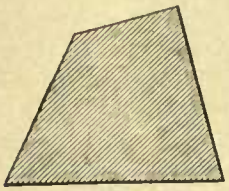


Fig. 16.—A Trapezium.

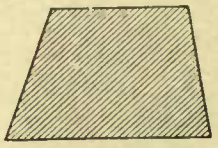


Fig. 17.—A Trapezoid.

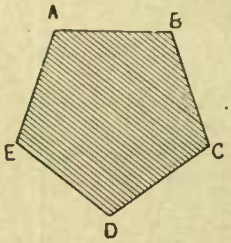


Fig. 22.—A Pentagon.

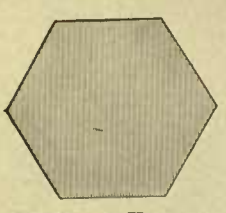


Fig. 23.—A Hexagon.

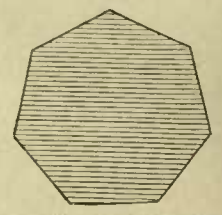


Fig. 24.—A Heptagon.

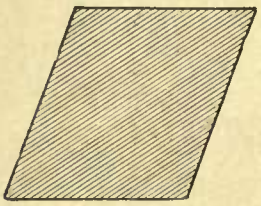


Fig. 18.—A Rhomboid.

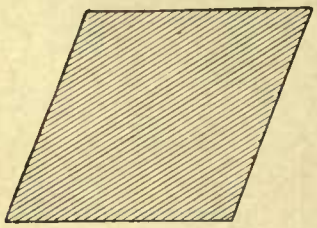


Fig. 19.—A Rhombus or Lozenge.

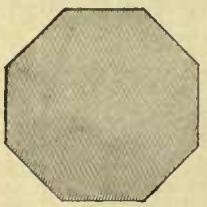


Fig. 25.—An Octagon.

Fig. 26.—A Decagon.

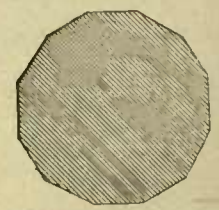


Fig. 27.—A Dodecagon.

Fig. 20.—An Equiangular Parallelogram Called a Rectangle.

Fig. 21.—An Equiangular and Equilateral Parallelogram Called a Square.

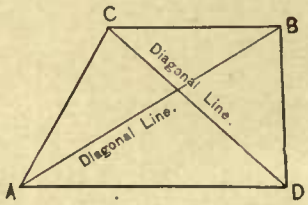


Fig. 28.—Diagonals.

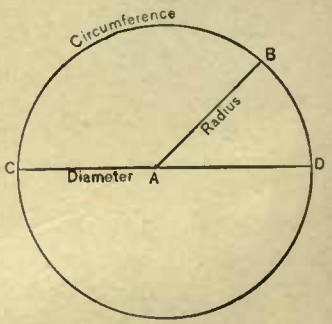


Fig. 29.—A Circle.

40. The **Rhomboid** has only the opposite sides equal, the length and width being different and its angles are not right angles. (Fig. 18.)

41. The **Rhombus, Lozenge** or diamond is a rhomboid all of whose sides are equal. (Fig. 19.)

42. The **Rectangle** is a parallelogram all of whose angles are right angles. (Fig. 20.)

43. The **Square** is an equilateral rectangle. (Fig. 21.)

44. A **Pentagon** is a plane figure of five sides. (Fig. 22.)

45. A **Hexagon** is a plane figure of six sides (Fig. 23.)

51. A **Diagonal** is a straight line joining two opposite angles of a figure, as A B and C D, Fig. 28.

CIRCLES AND THEIR PROPERTIES.

52. A **Circle** is a plane figure bounded by a curved line, everywhere equidistant from its center. (Fig. 29.) The term circle is also used to designate the boundary line. (See also Circumference.)

53. The **Circumference** of a circle is the boundary line of the figure. (Fig. 29.)

54. The **Center** of a circle is a point within the circumference equally distant from every point in its circumference, as A, Fig. 29.

55. The **Radius** of a circle is a line drawn from the center to any point in the circumference, as A B, Fig. 29, that is, half the diameter. The plural of radius is *radii*.

56. The **Diameter** of a circle is any straight line drawn through the center to opposite points of the circumference, as C D, Fig. 29.

57. A **Semicircle** is the half of a circle, and is

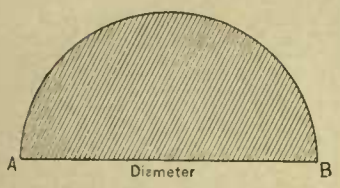


Fig 30.—A Semicircle.

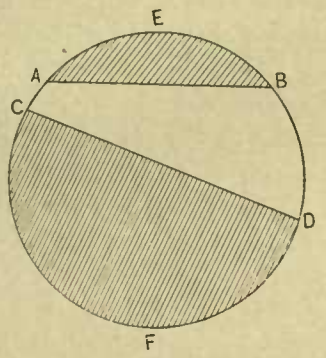


Fig. 31 —Segments.

bounded by half the circumference and a diameter. (Fig. 30.)

58. A **Segment** of a circle is any part of its surface cut off by a straight line, as A E B and C F D, Fig. 31.

59. An **Arc** of a circle is any part of the circumference, as A B E and C F D, Fig. 32.

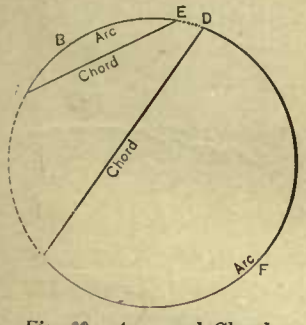


Fig. 32 —Arcs and Chords.

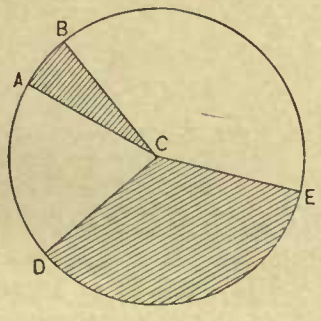


Fig. 33.—Secto s.

60. A **Chord** is a straight line joining the extremities of an arc, as A E and C D, Fig. 32.

61. A **Sector** of a circle is the space included between two radii and the arc which they intercept, as A C B and D C E, Fig. 33, and B A C, Fig. 34.

62. A **Quadrant** is a sector whose area is equal to one-fourth of the circle. (B A C, Fig. 34.) The two radii bounding a quadrant are at right angles.

63. A **Tangent** to a circle or other curve is a straight line which touches it at only one point, as E D and A C, Fig. 35. Every tangent to a circle is perpendicular to the radius drawn to the point of tangency. Thus E D is perpendicular to F D and A C to F B.

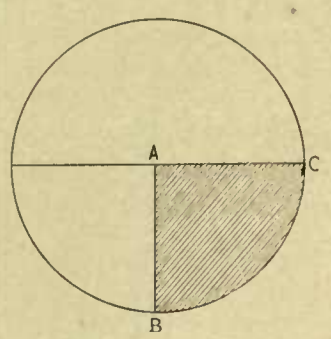


Fig 34.—A Quadrant.

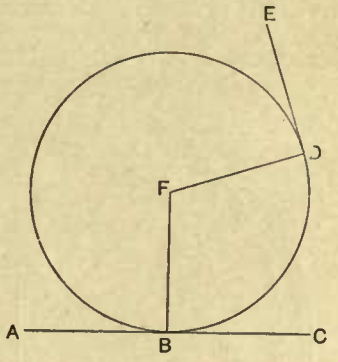


Fig. 35.—Tangents.

64. **Concentric** circles are those which are described about the same center. (Fig. 36.)

65. **Eccentric** circles are those which are described about different centers. (Fig. 37.)

66. Polygons are **inscribed in,** or **circumscribed by,**

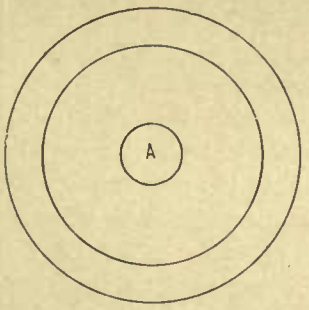


Fig. 36, - Concentric Circles.

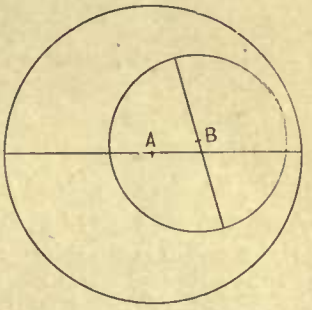
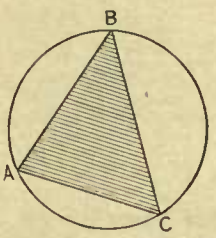


Fig 37 —Eccentric Circles.

circles when the vertices of all their angles are in the circumference. (Fig. 38.)

67. A circle is **inscribed** in a straight-sided figure when it is tangent to all sides. (Fig. 39.) All regular polygons may be inscribed in circles, and circles may



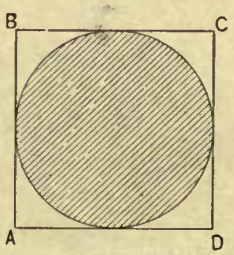


Fig. 38 —An Inscribed Triangle. *Fig. 39. —An Inscribed Circle.*

be inscribed in the polygons; hence the facility with which polygons may be constructed.

68. A **Degree.**—The circumference of a circle is considered as divided into 360 equal parts, called *degrees*

(marked °). Each degree is divided into 60 *minutes* (marked ′); and each minute into 60 *seconds* (marked ″). Thus if the circle be large or small the number of divisions is always the same, a degree being equal to

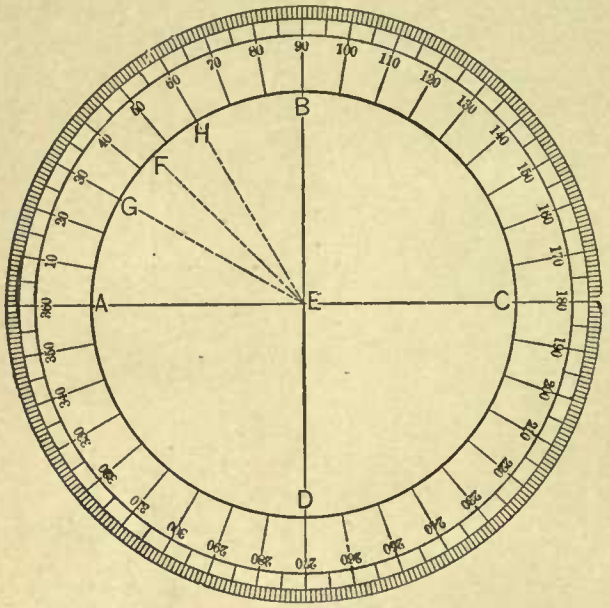


Fig. 40.—A Circle Divided into Degrees for Measuring Angles.

$\frac{1}{360}$th part of the whole circumference; the semicircle is equal to 180° and the quadrant to 90°. The radii drawn from the center of a circle to the extremities of a quadrant are always at right angles with each other; a right angle is therefore called an angle of 90° (A E B, Fig. 40). If a right angle be bisected by a straight line, it divides the arc of the quadrant also into two equal parts, each being equal to one-eighth of the whole circumference, or 45°, (A E F and F E B, Fig. 40); if the right angle were divided into three equal parts by straight lines, it would divide the arc into three equal parts, each containing 30° (A E G, G E H, H E B, Fig. 40). Thus the degrees of the circle are

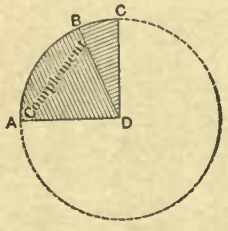


Fig. 41.—Complement.

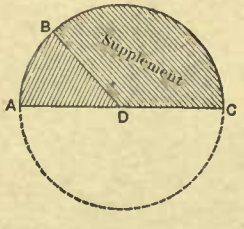


Fig. 42.—Supplement.

used to measure angles, therefore by an angle of any number of degrees, it is understood that if a circle with any length of radius be struck with one foot of the compasses in its vertex, the sides of the angle will intercept a portion of the circle equal to the number of degrees given. Thus the angle A E H, Fig. 40, is an angle of 60°. In the measurement of angles by the circumference of the circle, and in the various mathematical calculations based thereon, use is made of certain lines known as circular functions, always bearing a fixed relationship to the radius of the circle and to each other, which gives rise to a number of terms, some of which, at least, it is desirable for the pattern cutter to understand.

69. The **Complement** of an arc or of an angle is the difference between that arc or angle and a quadrant. In Fig. 41, A D B is the complement of B D C, and *vice versa*.

70. The **Supplement** of an arc or of an angle is the difference between that arc or angle and a semicircle.

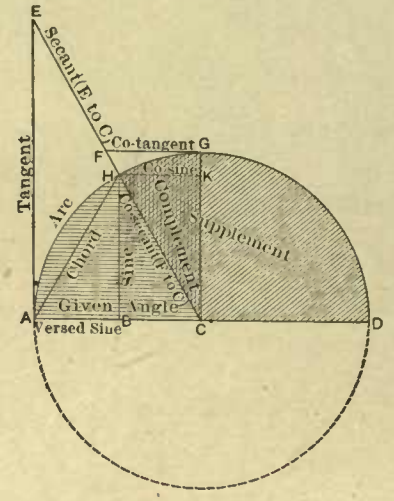


Fig. 43.—Diagram Showing the Circular Functions of the Arc A H or Angle A C H.

In Fig. 42, B D C is the supplement of A D B, and *vice versa*.

71. The **Sine** of an arc is a straight line drawn from one extremity perpendicular to a radius drawn to the other extremity of the arc. (H B, Fig. 43.)

72. The **Co-Sine** of an arc is the sine of the complement of that arc. H K, Fig. 43, is the sine of the arc A H.

73. The **Tangent of an Arc** is a line which touches the arc at one extremity, and is terminated by a line passing from the center of the circle through the other extremity of the arc. In Fig. 43, A E is the tangent of A H or of the angle A C H.

74. The **Co-Tangent** of an arc is the tangent of the complement. Thus F G, Fig. 43, is the co-tangent of the arc A H.

75. The **Secant** of an arc is a straight line drawn from the center of a circle through one extremity of that arc and prolonged to meet a tangent to the other extremity of the arc. (E C, Fig 43.)

76. The **Co-Secant** of an arc or angle is the secant of the complement of that arc or angle, as F C, Fig. 43.

77. The **Versed Sine** of an arc is that part of the radius intercepted between the sine and the circumference. (A B, Fig. 43.)

78. An **Ellipse** is an oval-shaped curve (Fig. 44), from any point in which, if straight lines be drawn to two fixed points within the curve, their sum will be always the same. These two points are called *foci* (F and H). The line A B, passing through the foci, is called the *major* or *transverse axis*. The line E G, perpendicular to the middle of the major axis, and extending from one side of the figure to the other, is called the *minor* or *conjugate axis*. There are various other definitions of the ellipse besides the one given here, dependent upon the means employed for drawing it, which will be fully explained at the proper place among the problems. (See definition 113.)

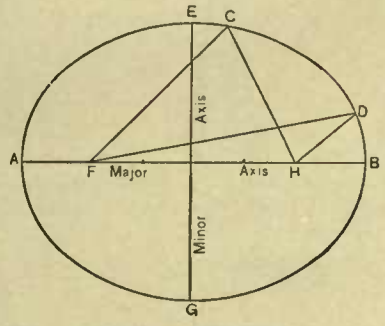


Fig. 44.—An Ellipse.

79. A **Parabola** (A B, Fig. 45) is a curve in which any point is equally distant from a certain fixed point and a straight line. The fixed point (F) is called the *focus*, and the straight line (C D) the *directrix*. In this figure any point, as N or M, is equally distant from F and the nearest point in C D, as H or K. (See definition 113.)

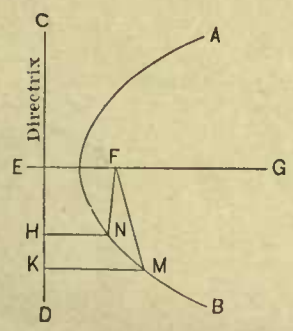


Fig. 45.—A Parabola.

80. A **Hyperbola** (A B, Fig. 46) is a curve from any point in which, if two straight lines be drawn to two fixed points, their difference shall always be the same. Thus, the difference between E G and G L is H L, and the difference between E F and F L is B L. H L and B L are equal. The two fixed points, E and L, are called *foci*. (See definition 113.)

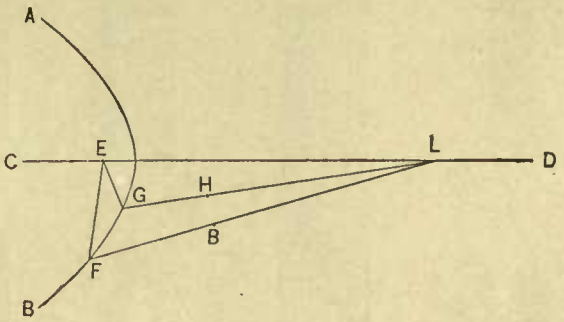


Fig. 46.—A Hyperbola.

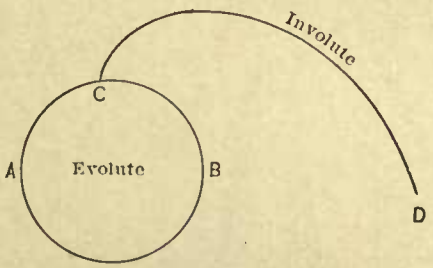


Fig. 47.—Evolute and Involute.

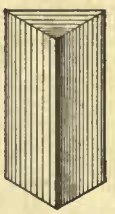


Fig. 48.—A Triangular Prism.

81. An **Evolute** is a circle or other curve from which another curve, called the *involute* or *evolutent*, is described by the aid of a thread gradually unwound from it. (Fig. 47.)

82. An **Involute** is a curve traced by the end of a string wound upon another curve or unwound from it. (Fig. 47.) (See also Prob. 84, Chapter IV.)

SOLIDS.

83. A **Solid** has length, breadth and thickness.

84. A **Prism** is a solid of which the ends are equal, similar and parallel straight-sided figures, and of which the other faces are parallelograms.

85. A **Triangular Prism** is one whose bases or ends are triangles. (Fig. 48.)

86. A **Quadrangular Prism** is one whose bases or ends are quadrilaterals. (Fig. 49.)

87. A **Pentagonal Prism** is one whose bases or ends are pentagons. (Fig. 50.)

88. A **Hexagonal Prism** is one whose bases or ends are hexagons. (Fig. 51.)

89. A **Cube** is a prism of which all the faces are squares. (Fig. 52.)

90. A **Cylinder**, or properly speaking a **Circular Cylinder**, is a round solid of uniform diameter, of which the ends or bases are equal and parallel circles. (Fig. 53.)

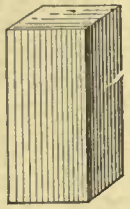


Fig. 49.—A Quadrangular Prism.

Fig. 50.—A Pentagonal Prism.

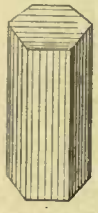


Fig. 51.—A Hexagonal Prism.

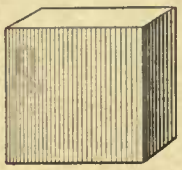


Fig. 52.—A Cube.

Fig. 53.—A Cylinder.

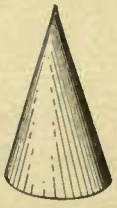


Fig 54.—A Cone.

Fig 55.—A Right Cone.

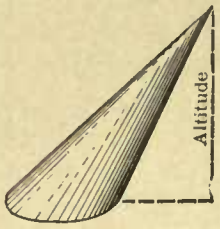


Fig. 56 —An Oblique or Scalene Cone.

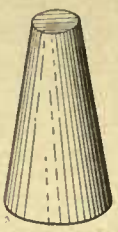


Fig. 57.—A Truncated Cone.

91. An **Elliptical Cylinder** is one whose bases are ellipses.

92. A **Right Cylinder** is one whose curved surface is perpendicular to its bases.

93. An **Oblique Cylinder** is one whose curved surface is inclined to its base.

94. A **Cone** is a round solid with a circle for its base, and tapering uniformly to a point at the top called the apex. (Fig 54.)

95. A **Right Cone** is one in which the perpendicular let fall from the vertex upon the base passes through the center of the base. This perpendicular is then called the *axis* of the cone. (Fig. 55.)

96. An **Oblique Cone** or **Scalene Cone** is one in which the axis is inclined to the plane of its base. (Fig. 56.)

97. A **Truncated Cone** is one whose apex is cut off by a plane parallel to its base. (Fig. 57.) This figure is also called a *frustum* of a cone. A pyramid may also be *truncated*. (See Figs. 69 and 70 and definition 112.)

98. A **Pyramid** is a solid having a straight-sided base and triangular sides terminating in one point or *apex*. Pyramids are distinguished as *triangular*, *quadrangular*, *pentagonal*, *hexagonal*, etc., according as the base has three sides, four sides, five sides, six sides, etc. (Figs. 58, 59 and 60.)

Fig 58.—A Triangular Pyramid.

Fig. 59.—A Quadrangular Pyramid.

Fig. 60.—An Octagonal Pyramid.

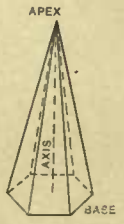


Fig. 61.—A Right Pyramid.

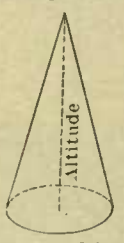


Fig. 62.—Altitude of a Cone.

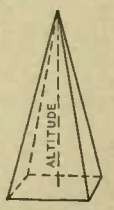


Fig 63 —Altitude of a Pyramid.

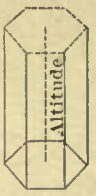


Fig. 64.—Altitude of a Prism.

Fig. 65 —Altitude of a Cylinder.

Fig. 66.—A Sphere, or Globe.

99. A **Right Pyramid** is one whose base is a regular polygon, and in which the perpendicular let fall from the apex upon the base passes through the center of the base. This perpendicular is then called the *axis* of the pyramid. (Fig. 61.)

100. The **Altitude** of a pyramid or cone is the length of the perpendicular let fall from the apex to the plane of the base. The altitude of a prism or cylinder is the distance between its two bases or ends, and is measured by a line drawn from a point in one base perpendicular to the plane of the other. (Figs. 56, 62, 63, 64 and 65.)

101. The **Slant hight** of a pyramid is the distance from its apex to the middle of one of its sides at the base. The *slant hight* of a cone is the distance

from its apex to any point in the circumference of its base.

102. A **Sphere** or **Globe** is a solid bounded by a uniformly curved surface, any point of which is equally distant from a point within the sphere called the center. (Fig. 66.)

103. A **Polyhedron** is a solid bounded by plane figures. There are five regular polyhedrons, viz.:

104. A **Tetrahedron** is a solid bounded by four equilateral triangles. It is one form of triangular pyramid. (Fig. 67.)

105. A **Hexahedron** is a solid bounded by six squares. The common name for this solid is *cube*, which see. (Fig. 52.)

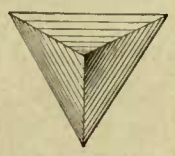


Fig. 67.—A Tetrahedron.

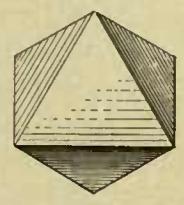


Fig. 68.—An Octahedron.

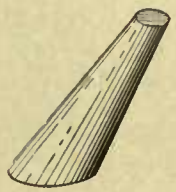


Fig. 69.—Frustum of a Scalene Cone.

106. The **Octahedron** is a solid bounded by eight equilateral triangles. (Fig. 68.)

107. The **Dodecahedron** is a solid bounded by twelve pentagons.

108. The **Icosahedron** is a solid bounded by twenty equilateral triangles.

109. An **Axis** is a straight line, passing through a body on which it revolves, or may be supposed to revolve. (Figs. 55 and 61.)

110. By the **Envelope** of a solid is meant the surface which encases or surrounds it, as the envelope of a cone.

111. **Intersection of Solids** is a term used to describe the condition of solids which are so joined and fitted to each other as to appear as though one passes through the other. The intersection of their surfaces forms the basis of the greater part of the problems of Chap. VI.

112. The **Frustum of a Cone** or **Frustum of a Pyramid** is that portion of the original solid which remains after the apex has been cut away upon a plane parallel to the base. (Figs. 57, 69 and 70.) When the cutting plane is oblique to the base of the solid they are spoken of as *oblique frustums*.

113. A **Conic Section** is a curved line formed by the intersection of a cone and a plane. The different conic sections are the triangle, the circle, the ellipse, the parabola and the hyperbola. When the cutting

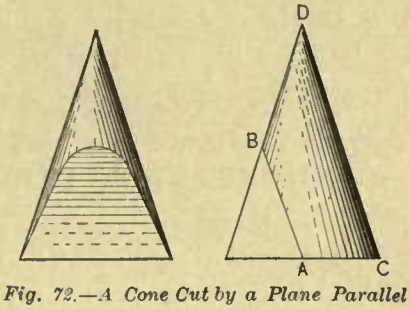


Fig. 72.—A Cone Cut by a Plane Parallel to One of Its Sides.

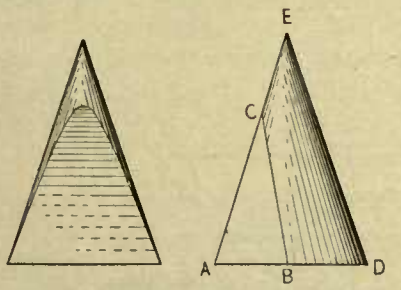


Fig. 73.—A Cone Cut by a Plane Which Makes an Angle with the Base Greater than the Angle Formed by the Side.

Fig. 70.—Frustum of a Pyramid.

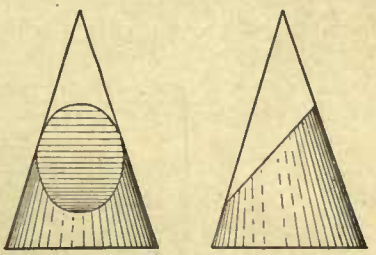


Fig. 71.—A Cone Cut by a Plane Obliquely through Its Opposite Sides.

plane passes obliquely through its opposite sides the resulting figure is called an *ellipse*. (Fig. 71.) (An ellipse is also an oblique section through a cylinder.) When a cone is cut by a plane parallel to one of its sides, the resulting figure is a *parabola*. Thus in Fig. 72 the cutting plane A B is parallel to the side of the cone C D. See definition 79. When the cutting plane makes a greater angle with the base than the side of the cone makes, or when it passes vertically through the cone to one side of the axis, the resulting figure is a *hyperbola*. Thus in Fig. 73 the angle A B C is greater than the angle A D E. See definition 80. The parabola and hyperbola resemble each other, both being incomplete figures, with arms extending indefinitely.

The ellipse is a complete figure, but of varying proportions, as the cutting plane is inclined more or less.

114. **Concave** means hollowed or curved inward,

Fig. 74.—Sections of Curved Surfaces.

said of the interior of an arched surface or curved line in opposition to convex. (Fig. 74.)

115. A **Convex** surface is one that is curved outward, that is regularly protuberant or bulging, when viewed from without. The opposite of convex is concave. (Fig. 74.)

ARCHITECTURAL TERMS.

116. The term **Cornice** is ordinarily used to designate any molded projection or collection of moldings which finishes or crowns the part to which it is affixed. The term in this sense is applicable in all styles of architecture. In classical architecture, however, it is confined to the upper division of the entablature, the whole has been omitted. The names of parts given in the illustration are such as are generally understood by architects and cornice makers. The cornice of classical architecture may contain simply a bed mold, planceer and crown mold, or it may contain, in addition, a dentil course or a modillion course, or both.

117. The **Entablature** was used by the ancients to finish a wall or colonnade (more especially the latter), and consisted of three parts, the cornice, the frieze and the architrave. (Fig. 75.)

118. The **Architrave,** the lower division of the entablature, was in reality a lintel used to span the space between the columns, but its form was maintained when used above a wall. In modern imitations of the antique styles the molded portion is frequently used without the fascias, in which case it is commonly known as the *foot mold.* (Fig. 75.) The term architrave is also used to designate the molding and fascias running around an arch or a window opening.

119. The **Frieze,** the middle division of the entablature, is really a continuation of the wall surface to add hight and effect to the building, and was originally intended for the display of symbols, inscriptions, ornaments, &c., appropriate to the use of the building of which it was a part. It is sometimes treated very plainly and sometimes receives considerable ornamentation, being subdivided into panels or enriched by

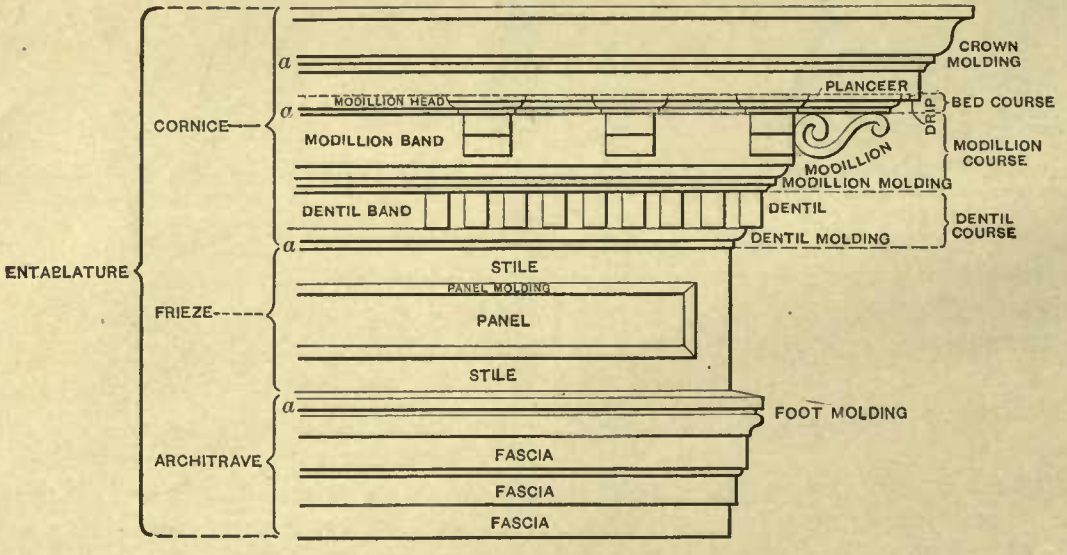


Fig. 75.—The Entablature and Its Parts.

of which, according to modern ideas, might be considered as a cornice. The distinction is shown in Fig. 75, which shows an entablature of a design adaptable to sheet metal construction, and in which all enrichment scrolls, etc. The terms *plain frieze*, designating a frieze devoid of ornamentation, and *frieze-piece* or *frieze-panel*, are used to designate one of the parts of which a frieze is constructed. (Fig. 75.)

120. **Arch.** The curved top of an opening in a wall. The arch of masonry is constructed of separate blocks and is supported only at the extremities. The joint lines between the blocks are disposed in the direction of radii of the curve, thus enabling the arch to support the weight of the wall above the opening. When in classical designs its face is finished with moldings their proper profile is that of an architrave. (Fig. 75.) The level lines at which the curve of the arch begins are called the *springing lines*. Sometimes the lower stones of the arch rise vertically a short distance from the supports before the springing lines are reached, in which case the arch is said to be *stilted*.

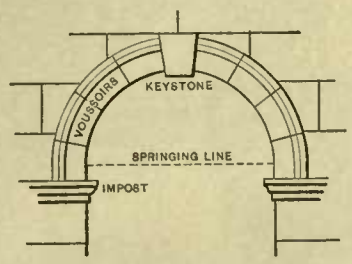


Fig. 76.—A Semicircular Arch.

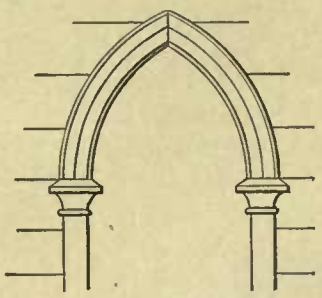


Fig. 77.—A Pointed Arch.

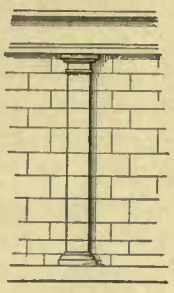


Fig. 80.—A Pilaster.

The stones composing the arch are called the *voussoirs*, and the middle or top stone is called the *keystone*. The supports below the ends of the arch are called *imposts*.

Arches are usually *semicircular* (Fig. 76), *semi-elliptical*, *segmental*, *pointed* (Fig. 77) or *Moresque* (*horse-shoe*) (Fig. 78) in shape, according to the style of architecture with which they are used.

The top of an opening may be perfectly level and yet composed of wedge-shaped blocks so combined as to be self-supporting, in which case it is called a *flat arch*. (Fig. 79.)

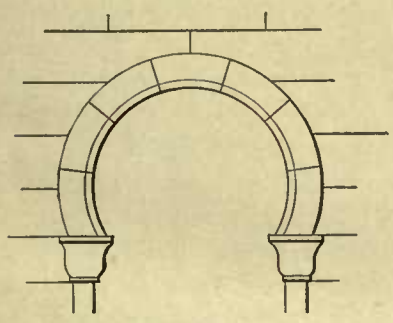


Fig. 78.—A Moresque Arch.

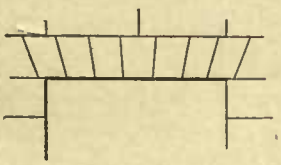


Fig. 79.—A Flat Arch.

121. A **Column** is a vertical shaft or pillar round in plan, designed as a support for an entablature. It consists of three parts: a *base*, a *shaft* and a *capital*.

122. An **Engaged Column** is a column placed against the face of a wall or other surface, from which it projects one-half or more than one-half its diameter.

123. A **Pilaster** differs from a column in that it is square in plan instead of round and is usually engaged within a wall. (Fig. 80.)

124. **Pedastal.** A structure designed to support a column, statue, vase or other object. It is by some described as the foot of a column, but is, properly speaking, not a part of it. It consists of three parts, a *base*, a middle portion cubical in shape called a *die* and a *cap* or *cornice*. It is also used as a finish at the ends of a balustrade course.

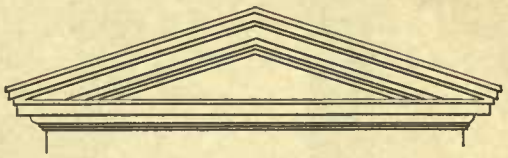


Fig. 81.—An Angular Pediment.

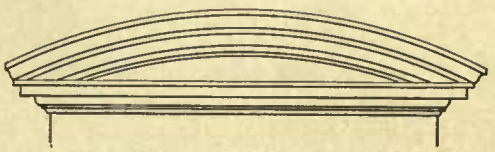


Fig. 82.—A Segmental Pediment.

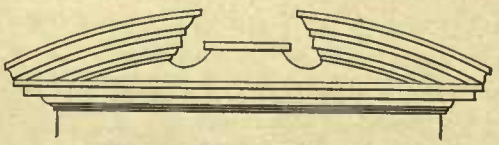


Fig. 83.—A Broken Pediment.

125. A **Pediment** is a triangular or segmental ornamental facing over a portico, door, window, etc. (Figs. 81, 82 and 83.

126. A **Broken Pediment** is one, either in the form of a gable or a segment, which is cut away in its central portion for the purpose of ornamentation. (Fig. 83.)

127. A **Gable** is the vertical triangular end of a house or other building, from the cornice or eaves to the top.

128. A **Lintel Cornice** is a cornice above or sometimes including a lintel. This term is very generally used to designate the cornice used above the first story of stores. (Fig. 84.)

129. A **Deck Cornice** or **Deck Molding** is the cornice

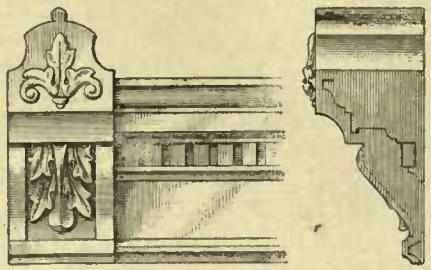


Fig. 84.—A Lintel Cornice.

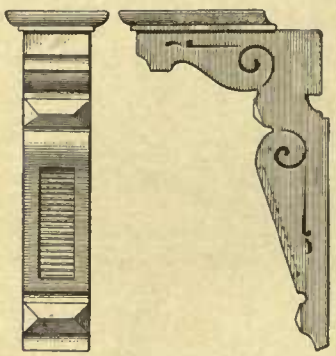


Fig. 85.—A Bracket.

or molding used to finish the edge of a flat roof where it joins a steeper portion.

130. A **Bracket,** as used in sheet metal work, is simply an ornament of the cornice. Brackets in stone architecture were originally used as supports of the parts coming above them. Hence modern architecture has kept up that idea in their designs. (Fig. 85.)

131. **Modillions** are also cornice ornaments, and differ from brackets only in general shape. (Fig. 86.) While a bracket has more depth than projection, modillions have more projection than depth.

132. A **Dentil** is a cornice ornament smaller than a modillion, which in shape usually represents a solid with plain rectangular face and sides. Dentils are never used singly, but in courses, the spaces between them being less than their face width. (Fig. 76.)

133. A **Corbel** is a modified form of bracket. It is used to terminate the lower parts of window caps, and also forms the support for arches, etc., in gothic forms.

Fig. 86.—A Modillion.

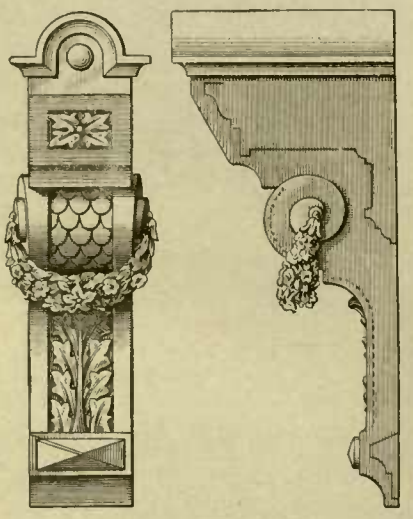


Fig. 87.—A Head Block.

134. A **Head Block** or **Truss** is a large terminal bracket in a cornice, projecting sufficiently to receive all the moldings against its side, thus forming a finish to the end of the cornice. (Fig. 87.)

135. A **Stop Block** is a block-shaped structure, variously ornamented, which is placed above the end

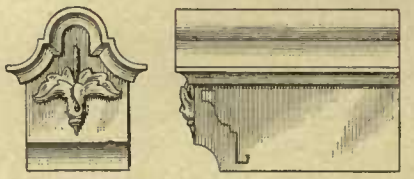


Fig. 88.—A Stop Block.

Fig. 89.—A Pinnacle.

bracket in a cornice, and which projects far enough to receive against its side the various moldings occurring above the brackets, forming an end finish. (Fig. 88.)

136. A **Pinnacle** is a slender turret or part of a building elevated above the main building. A small spire. (Fig. 89.)

137. A **Finial** is an ornament variously designed, placed at the apex of a pediment, gable, spire or roof.

138. **Capital.**—The upper member or head of a column or pilaster. It may vary in character according to the style of architecture with which it is employed, from a few simple projecting moldings around the top of the column to an elaborately foliated ornament. The lower-

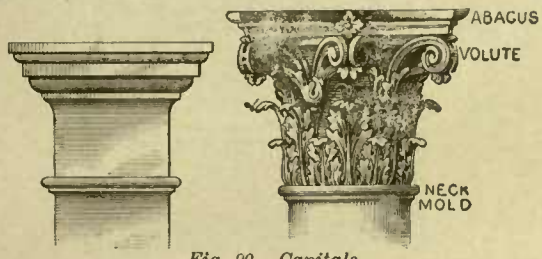


Fig. 90.—Capitals.

most mold is called the *neck mold* and the uppermost member sustaining the weight of the lintel or arch above is called the *abacus*. (Fig. 90.)

139. **Panel.**—A sunken compartment having molded edges used to ornament a plane surface, as a frieze ceiling, planceer or tympanum. A panel may, however, be raised instead of sunken.

The margin or space between the sides of the panel and the edges of the surface in which it is placed is usually made equal all around and is called the *stile*.

140. A **Volute** is a spiral scroll used as the principal ornament of a capital and is placed under the corners of the abacus. For method of drawing the volute see Probs. 81 and 82, Chap. IV.

141. A **Molding** is an assemblage of forms projecting beyond the wall, column or surface to which it is affixed. (See first part of Chap. V.)

142. **Crown Molding** is the term applied to the upper or projecting member of a cornice. (Fig. 75.)

143. **Planceer** or **Plancher** is the ceiling or under side of the projecting part of a cornice. (Fig. 75.)

144. The **Bed Moldings** of a cornice are those moldings forming the lower division of the cornice proper, and which are made up of the bed course, modillion course and dentil course. (Fig. 75.)

145. The **Bed Course** is the upper division of the bed moldings, the part with which the bracket heads and modillion heads ordinarily correspond, and against which they miter. (Fig. 75.)

146. The **Modillion Course** of a cornice embraces the modillions and all the moldings which are immediately back of and below them. The plain surface lying back of or between the modillions is called in sheet metal work the *modillion band*, and the molding immediately below them the *modillion molding*. (Fig. 75.)

147. The **Dentil Course** of a cornice embraces the dentils and all the moldings to which the dentils are attached as ornaments, comprising the *dentil band* and *dentil molding*. (Fig. 75.)

148. **Foot Molding** is the common term used to designate the lower molding in a cornice. It is frequently in this connection used in the sense of architrave. (Fig. 75.)

149. A **Bracket Molding,** also called *bracket head*, is the molding around the upper part of a bracket, and which generally members with the bed molding, against which it finishes. (Fig. 75.)

150. A **Gable Molding** is an inclined molding which is used in the finish of a gable.

151. A **Ridge Molding** is a molding used to cap or finish a ridge. It is also called a *ridge capping* or simply *ridging*.

152. A **Hip Molding** is a molding used to protect and finish the hips or angles of a roof. It is very frequently included in the more general term *ridging*.

153. A **Fascia** is a plain band or surface below a molding, or, in other words, the unornamented face of a portion of a cornice or architrave. (Fig. 75.)

154. A **Fillet** is a narrow plain member of a molding used to finish or separate the different forms (*a a a a* Fig. 75 are fillets.)

155. A **Drip** is a downward projecting member in a cornice or in a molding, used to throw the water off from the other parts. (Fig. 75.)

156. **Soffit** is the term applied to the under side of a projecting molding, cornice or arch.

157. A **Sink** is a depression in the face of a piece

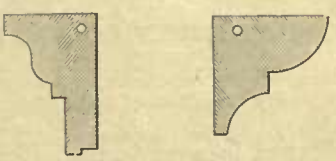


Fig. 91.—Stays.

of work or in a plain surface. (See face of bracket, Fig. 85, side of modillion, Fig. 86.)

158. **Incised Work** is a style of ornamentation consisting of fine members and irregular lines, sunken or cut into a plain surface. (See side of bracket Fig. 85.)

159. The **Stay** of a molding is its shape or profile cut in sheet metal. (Fig. 91.)

160. **Rake Moldings** are those which are inclined, as in a gable or pediment; since to miter a rake molding with a level return under certain conditions necessitates a change or modification of profile in one or the other of the moldings *to rake* means to make such change of profile.

161. A **Raked Molding,** therefore, is a term describ-

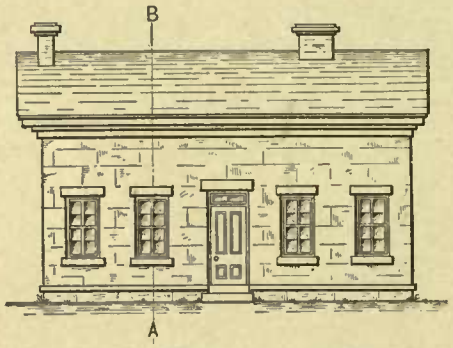


Fig. 92.—Elevation of a House.

ing a molding of which the profile is a modification of some other profile.

162. A **Raked Profile** or **Raked Stay** describes the profile or stay which has been derived from another profile or stay, by certain established rules, in a process like that of mitering a horizontal and inclined molding together.

163. The **Normal Profile** or **Normal Stay** is the original profile or stay from which the raked profile or stay has been derived.

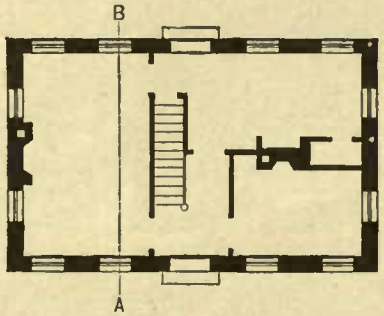


Fig. 93.—Plan of a House.

164. A **Flange** is a projecting edge by which a piece is strengthened or fastened to anything.

165. A **Hip** is the external angle formed by the meeting of two sloping sides or skirts of a roof which have their wall plates running in different directions.

DRAFTING TERMS.

166. **Projection** is that department of geometrical drawing which treats of the drawing of elevations, plans, sections and perspective views. There are four kinds of projections, viz.: Orthographic, Isometrical, Cavalier and Perspective. Chapter III is devoted to an explanation of the principles of orthographic projection.

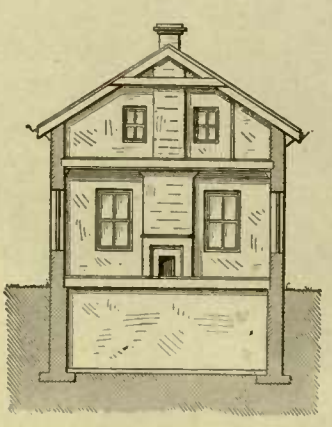


Fig. 94.—Section of House on Line A B of Plan and Elevation.

167. An **Elevation** is a geometrical projection of a building or other object on a plane perpendicular to the horizon. (Fig. 92.)

168. A **Plan** is the representation of the parts as they would appear if cut by a horizontal plane. (Fig. 93.)

169. A **Section** is a view of the object as it would appear if cut in two by a given vertical or horizontal plane. (Fig. 94.) In the one case the resulting view is called a *vertical section*, and in the other a *horizontal*

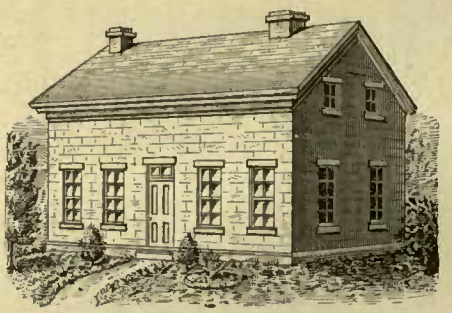


Fig. 95.—Perspective View of House.

section. Oblique sections are representations of objects cut at various angles.

170. A **Perspective** is a representation of a building or other object upon a plane surface as it would appear if viewed from a particular point. (Fig. 95.)

171. A **Detail Drawing** or **Working Drawing** is a drawing, commonly full size, for the use of mechanics in constructing work.

172. A **Scale Drawing** is one made of some scale less than full size.

173. A **Miter** is a joint in a molding, or between two pieces not moldings, at any angle.

174. A **Butt Miter** is the term applied to the cut made upon the end of a molding to fit it against another molding or against a surface.

175. A **Gable Miter** is the name applied to the miter either at the peak or at the foot of the moldings of a gable or pediment.

176. A **Rake Miter** is a miter between two moldings, one of which has undergone a modification of profile to admit of the joint being made.

177. **Square Miter** is the common term for a joint at right angles, or at 90°.

178. An **Octagon Miter** is a miter joint between two sides of a regular octagon, or between any two pieces at an angle of 135°.

179. An **Inside Miter** indicates a joint at an interior or re-entrant angle.

180. An **Outside Miter** is a joint at an exterior angle.

181. The **Development** of a surface is the process of finding, from a drawing of a rounded form, a shape or pattern upon a flat surface which, when cut out and bent or formed as indicated by that drawing, will constitute its envelope; or, in other words, the stretching out flat of a surface shown by a drawing to be curved.

Alphabetical List.

In the following list all words are arranged in alphabetical order, the figure following each referring to the number of the definition in the list preceding:

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CHAPTER II.

Drawing Tools and Materials.

To the person about to begin a new occupation the first consideration is, what tools and materials does he need? In the following description of the appliances, tools and materials likely to be of service to the pattern cutter in the class of work in which he is supposed to be the most interested, the description is limited to articles of general use. Those who are interested in drawing tools and materials upon a broader basis than here presented are referred to special treatises on drawing and to the catalogues of manufacturers and dealers in drawing materials and drawing instruments.

Drafting Tables.—A drafting table suitable for a jobbing shop should be about five feet in length and three to four feet in width. It is better to have a table somewhat too large, than to have one so small that it is frequently inadequate for work that comes in. In hight the table should be such that the draftsman, as he stands up, may not be compelled to stoop to his work. While for some reasons it is desirable that the table should be fixed upon a strong frame and legs, for convenience such tables are generally made portable. Two horses are used for supports and a movable drawing board for the top. A shallow drawer is hung by cleats fastened to the under side, and is arranged for pulling either way. Sometimes horizontal pieces are fastened to the legs of the horses, and a shelf or shelves are formed by laying boards upon them. Fig. 96 shows such a table as is here described. When properly made, using heavy rather than light material, such a table is quite solid and substantial, and when not in use can be packed away into a very small space.

For cornice makers' use, a table similar in construction to the one described and illustrated (Fig. 96) is well adapted. Its dimensions, however, considering the extremes of work that are likely to arise, should be twelve to fourteen feet in length by about five feet in breadth. Three horses are necessary, and two drawers may be suspended. For very large work, one draftsman or pattern cutter will require the whole table, but for ordinary work, such as window caps, cornices, etc., two men can work at it without interfering with or incommoding each other.

Various woods may be used for drawing tables, but white pine is the cheapest and best for the purpose. Inch and one-half to two-inch stuff will be found economical, as it allows for frequent redressing —made necessary by pricking in the process of pattern cutting. Narrow stuff, tongued and grooved together or joined by glue, is preferable to wide plank, as it is

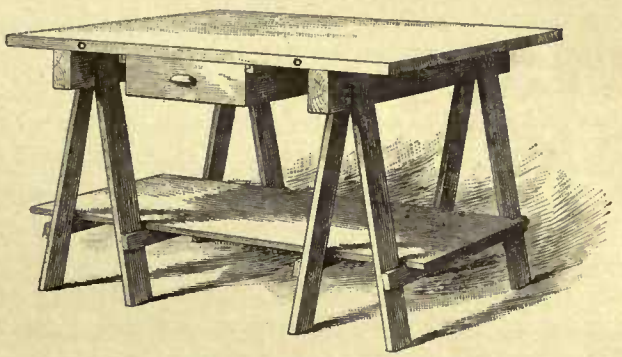

Fig. 96.—Drafting Table.

less liable to warp. Rods run through the table edgeways, as shown in Fig. 96, are desirable for drawing the parts together and holding them in one compact piece. The nut and washer are sunk into the edge of the table, a socket wrench being used to operate them.

A drafting table should be an accurate rectangle —that is, every corner should be a right angle, and the opposite sides should be parallel. The edges should be exactly straight throughout their length. Methods of testing drafting tables and drawing boards, with reference to these points, are given below. The usual way of adjusting a table or board to make it accurate is to plane off its edges as required. But this is a task less simple than it appears. It requires the nicest skill and accuracy to render it at all satisfactory.

When it is remembered that no matter how well seasoned the lumber employed may be the table will be affected by even slight changes in the atmosphere, it is apparent that dressing off the edges with a plane, under certain circumstances, might be constantly required. For great accuracy, adjustable metal strips may be fastened to the edges of the table in such a manner that, by simply turning a few screws, any variation in the table may be compensated. This arrangement may be accomplished in the following manner: The edge of the table on all sides is cut away so as to allow a bar of steel, say one-eighth or one-sixteenth of an inch thick and about an inch wide, to lie in the cutting, so that its surface is even with the face of the table, with its outer edge projecting somewhat beyond the edge of the table. Slotted holes are made in the table through which bolts with heads countersunk into the metal are passed for holding the steel strips. A washer and nut are used on the under side of the table. The adjustment required is, of course, very slight. The edge of the metal projecting slightly, as described, is well adapted for receiving the head of the T-square, rendering the use of that instrument more satisfactory than when it is used against the plane edge of the table, even if equally accurate.

Drawing Boards.—The principal difference between a drafting table and a drawing board is in the size. The same general requirements in point of accuracy, etc., are necessary in each. Convenient sizes of tables for various uses have been mentioned, but to point out sizes of boards for different purposes is not so easy a matter, their application being far more extended and their use more general. A drawing board may be made of any required size, from the smallest for which such an article is adapted up to the extreme limit consistent with convenience in handling. In the larger sizes the general features of construction noted under drafting tables are entirely applicable, save that thinner material should be used in order to reduce the weight. In small sizes there is a choice between several different modes of construction, two or three of which will be described, although boards of almost any required construction can be purchased ordinarily of dealers in drawing tools and materials at lower prices than they can be made. However, it is very convenient, in many cases, to have boards made to order, and therefore detailed descriptions of good constructions are desirable. Any carpenter or cabinet maker should be able to do the work.

In Fig. 97 is shown a very common form of drawing board, consisting of a pine wood top with hardwood ledges. The ledges are put on by means of a dovetail, tapering probably one-half inch in the width of the board, so that while allowing entire freedom for

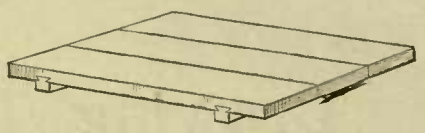

Fig. 97.—Drawing Board, with Ledges.

seasoning there is no danger of cracking the board, and they may be driven tight as required. Where it is desirable to use screws in the ledges they are passed through slotted holes furnished with a metallic bushing.

In Fig. 98 is shown a still simpler form of board, which is adapted only for the smallest sizes. Hard-

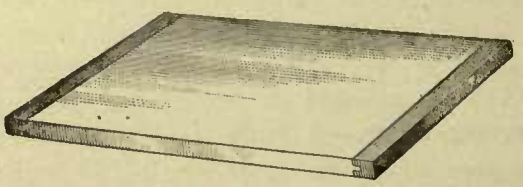

Fig. 98.—Drawing Board, with Tongued and Grooved Cleats.

wood strips are tongued and grooved onto the ends to prevent warping, as shown in the engraving. By using strips of wood thicker than the board, keeping their upper surfaces flush with the surface of the board, it may be constructed so as to have the advantage of ledges on the under side equivalent to those shown in Fig. 97.

Fig. 99 shows a construction which, while being

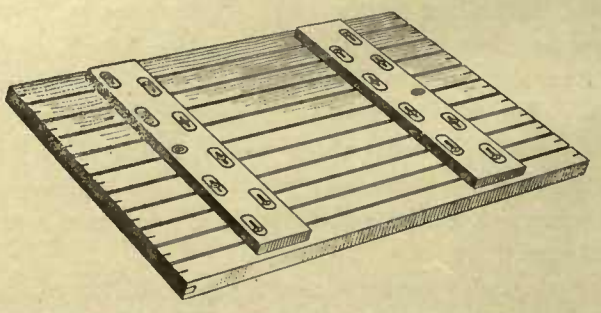

Fig. 99.—Bottom View of Drawing Board, with Grooved Back and Cleats Attached with Slotted Holes.

somewhat more expensive than the others, is undoubtedly much better. It is made of strips of pine wood, glued together to make the required width. A

pair of hard-wood cleats is screwed to the back, the screws passing through the cleats in oblong slots with brass bushings, which fit closely under the heads and yet allow the screws to move freely when drawn by the shrinkage of the board. To overcome the tendency of the surface to warp, a series of grooves are sunk in half the thickness of the board over the entire back. To make the working edges perfectly smooth, allowing an easy movement with the T-square, a strip of hard-wood is let into the end of the board. The strip is afterward sawn apart at about every inch, to admit of contraction. In the construction of such boards additional advantage is obtained by putting the heart side of each piece of wood to the surface.

As pattern cutting is nothing if not accurate, it is a matter of the utmost importance that the drawing board or table should be perfectly rectangular. If each angle is a right angle—if its opposite sides are exactly parallel—the T-square may be used at will from any portion of it with satisfactory results. If the board is accurate the drawing will be accurate If the board is not accurate the drawing can only be made accurate at

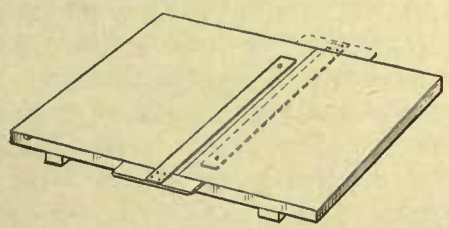

Fig. 100.—Testing the Sides of a Drawing Board.

the cost of extra trouble and care. While it is easy to get a board approximately correct by ordinary means, one or two simple tests will serve to point out inaccuracies for correction which by ordinary means would pass unnoticed. For such tests a T-square and an ordinary two-foot steel square that are exactly correct will be required.

Having made the opposite sides and ends of the board as nearly accurate as possible, place the head of the T-square against one side, as shown in Fig. 100, and with a hard pencil sharpened to a chisel edge, or with the blade of a knife, scribe a fine line across the board. Then carrying the T-square to the opposite side of the board, as shown by the dotted lines, bring the edge of the blade to the line just scribed and see that it exactly coincides throughout its length with the line. Repeat this operation at frequent intervals along the edges of the board, both at the sides and ends. Remove any small inaccuracies on the edges by means of a file or fine sand paper folded over a block of wood. Careful work in this manner will produce very satisfactory results.

A means of testing a board with reference to the accuracy of the corners is shown in Fig. 101. A carpenter's try-square or an ordinary steel square used

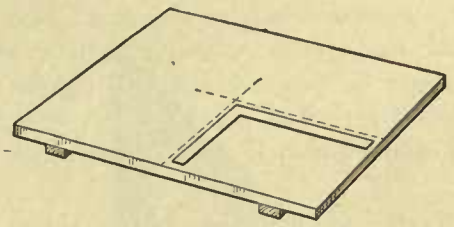

Fig. 101.—Testing the Corner of a Drawing Board.

upon the corners does not ordinarily reach far enough in either direction to satisfactorily determine that the adjacent end and side are perpendicular to each other; hence it is desirable to obtain some kind of a test with reference to this point from the middle portions of the edges. With the head of the T-square placed against one side of the board draw a fine line, as indicated by the dotted line in the engraving, and from one end draw a second line in the same manner. If the side and end are at right angles the two lines will coincide with the arms of a square when placed as shown in the engraving. Repeat this operation for each of the corners. The two methods above described for testing drawing boards, especially when used together, cannot fail to enable any one to obtain a board as nearly accurate as it is possible to make it. Modifications of the methods here given, and based upon the same principles, will suggest themselves to any one who will give the matter careful thought.

Straight-Edges.—In connection with every set of drawing instruments there should be one or more

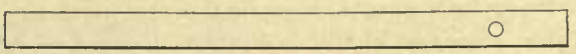

Fig. 102.—Straight-Edge.

straight-edges. If nothing but pencil or pen lines are to be made upon paper, those of hard-wood or hard rubber will answer very well; but if lines are to be drawn upon metal, steel is the only satisfactory material. The length of the straight-edge must be determined by the work to be done, but a safe rule is to have it somewhere near the length of the table or board. Of course this is out of the question in cornice work, where tables are frequently upward of

twelve feet in length. In such cases the size of the material to be cut determines this matter. If iron 96 inches long is used, the straight-edge, for convenience, should not be less than 8½ feet. If shorter iron is regularly used, a shorter straight-edge will answer. In cornice work, two and even three different lengths are found advantageous. The longest might be as just described; a second might be about four feet in length and made proportionately lighter, while the smallest might be two feet and still lighter than the four-foot size. Instead of the latter, however, the long arm of the common steel square serves a good purpose.

For tinners' use in general jobbing shops, a three-foot straight-edge in many cases, and a four-foot one in a few instances, will be found very convenient. Some mechanics desire their straight-edges graduated, the same as a steel square, into inches and fractions. There is, however, no special advantage in this; it adds considerably to the cost, without rendering the tool more useful.

A hole should be provided in one end of the straight-edge for hanging up. It should always be suspended when not in use, as in that position it is not liable to receive injury.

It is almost superfluous to add that straight-edges must be absolutely accurate, for if inaccurate they would belie their name. A simple and convenient method of testing straight-edges is to place two of them together by their edges, or a single one against the edge of a square, and see if light passes between them. If no space is to be observed between the edges it is satisfactory evidence that they are as nearly straight as they can be made by ordinary appliances. In addition to having the edges straight it is also necessary to have the two sides parallel.

T-Squares.—With this instrument, as with almost all drawing instruments, there is the choice of various qualities, sizes and kinds, and selection must be made with reference to the kind of work that is to be performed. Whatever quality may be chosen, the desirable features of a T-square are strict accuracy in all respects, and a thin, flat blade that will lie close to the paper. For most purposes a fixed head, as shown in Fig. 103, is preferable. For drawings in which a great number of parallel oblique lines are required, and particularly where a small size T-square can be used, a swivel head, as shown in Fig. 104, is sometimes desirable. The objectionable feature about a swivel head is the difficulty of obtaining positive adjustment. When made in the ordinary manner, and depending upon the friction of the nut of a small bolt for holding the head in place, it is almost impossible to obtain a bearing that can be depended upon during even a simple operation. In practice it is found to be far less trouble to work from a straight-edge—properly placed across the board and weighted down or otherwise held

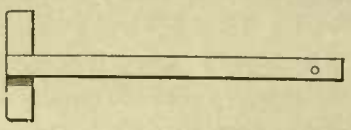

Fig. 103.—T-Square with Fixed Head.

in place—by means of a triangle or set-square, as greater accuracy is thus assured.

In point of materials, probably a T-square having a walnut head and maple blade is as satisfactory as any. This kind is the cheapest and is generally considered the best for practical purposes. A good article, but of higher price, consists of a walnut head with a hard-wood blade, edged with some other kind of wood. Still another variety has a mahogany blade edged with ebony. T-squares constructed with cast-iron head—open work finished by japanning—with nickel-plated steel blade, are also to be had from dealers. They are also made with a hard rubber blade, of which Fig. 104 is an illustration. The liability to fracture, however, by dropping necessitates the greatest care in use; otherwise hard rubber makes a very desirable article and is the favorite material with many draftsmen.

As to size, T-squares should be selected with reference to the use to be made of them. Generally, the blade should be a very little less in length than the width of the table or board upon which it is to be

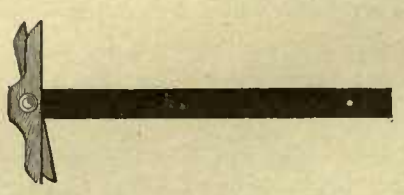

Fig. 104.—T-Square with Fixed and Swivel Head.

used. Where a large board or a table is used it will be found economical to have two instruments of different sizes.

The Steel Square.—One of the most useful tools in connection with the pattern cutter's outfit is an ordinary steel square. The divisions upon it concern him much less than its accuracy. He seldom requires other divisions than inches and eighths of an inch; therefore in selection the principal point to be considered is that

of accuracy. The finish, however, is a matter not to be overlooked. Since a nickel-plated square costs but a trifling advance upon the plain article, it is cheaper in the long run to have the plated tool.

A convenient method of testing the correctness of the outside of a square, and one which can be used at the time and place of purchase, is illustrated in

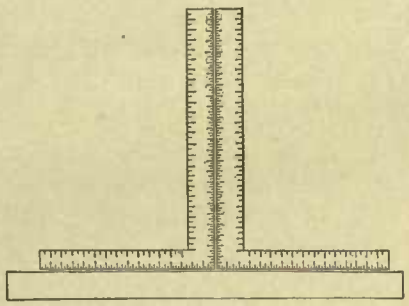

Fig. 105.—Testing the Exterior Angle of a Steel Square.

Fig. 105. Two squares are placed against each other and against a straight-edge, or against the arm of a third square. If the edges touch throughout, the squares may be considered correct.

Having procured a square which is accurate upon the outside, the correctness of the inside of another square may be proven, as shown in Fig. 106. Place one square within the other, as shown. If the edges

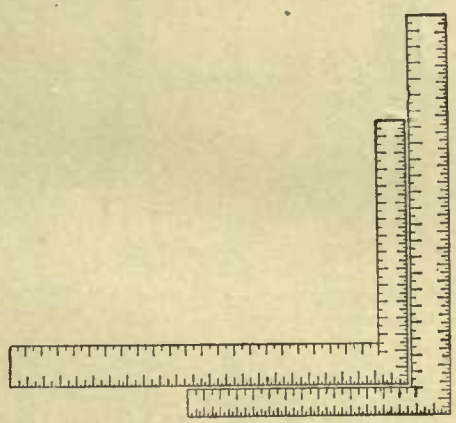

Fig. 106.—Testing the Interior Angle of a Steel Square.

fit together tightly and uniformly throughout, the square may be considered entirely satisfactory.

An accurate square is especially desirable, as it affords the readiest means of testing the T-square and the drawing table and board, as elsewhere described. The greatest care should be given, therefore, to the selection of a square. For all ordinary purposes the two-foot size is most desirable. In some cases the one-foot size is better suited. Many pattern cutters on cornice work like to have both sizes at their command, making use of them interchangeably, according to the nature of the work to be done.

Triangles, or Set Squares.—In the selection of triangles, the draftsman has the choice in material be-

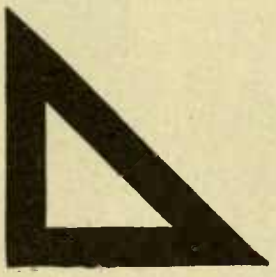

Fig. 107.—Open Hard Rubber Triangle or Set Square, 45 × 45 × 90 Degrees.

tween pear wood; mahogany, ebony lined; hard rubber; German silver, and steel, silver or nickel plated. In style he has the choice between open work, of the form shown in Fig. 107, and the solid, as in Fig. 108. In shape, the two kinds which are adapted to the pattern cutter's use are shown in Figs. 107 and 108, the latter being described as 30, 60 and 90 degrees, or 30 by 60 degrees, and the former as 45, 45 and 90 degrees, or simply 45 degrees. The special uses of each of these two tools are shown in the chapter on Geometrical Problems (Chap. IV). In size, the pattern cutter requires large rather than small

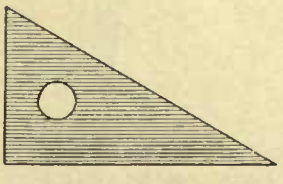

Fig. 108.—Hard Wood Triangle or Set Square, 30 × 60 × 90 Degrees.

ones. If he can have two sizes of each, the smaller should measure from 4 to 6 inches on the side, and the larger from 10 to 12 inches; but if only a single size is to be had, one having dimensions intermediate to those named will be found the most serviceable.

The value of a triangle, for whatever purpose used, depends on its accuracy. Particularly is this to be said of the right angle, which is used more than either of the others. A method of testing the accuracy of the right angle is shown in Fig. 109. Draw the line A B

with an accurate ruler or straight-edge. Place the right angle of a triangle near the center of this line, as shown by D C B, and make one of the edges coincide with the line, and then draw the line D C against the

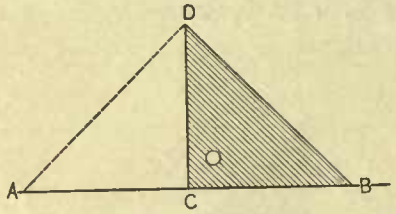

Fig. 109.—Testing the Right Angle of a Triangle.

other edge. Turn the triangle into the position indicated by D C A. If it is found that the sides agree with A C and C D, it is proof that the angle is a right angle and that the sides are straight.

Besides the kinds of triangles described above, a fair article can be made by the mechanic from sheet zinc or of heavy tin. Care must, however, be taken in cutting to obtain the greatest possible accuracy. For many of the purposes for which a large size 45 degree triangle would be used the steel square is available, but as the line of the hypothenuse is lacking, it cannot be considered a substitute.

Compasses and Dividers.—The term compasses is applied to those tools, of various sizes and descriptions, which hold a pencil and pen in one leg, and are used for drawing circles, while dividers are those tools which, while of the same general form as compasses, have both legs ending in fixed points, and are used for measuring spaces. A special form of dividers—used exclusively for setting off spaces, as in the divisions of a profile line—is called spacers, as illustrated and described below.

A pair of compasses consists of the parts shown in Fig. 110, being the instrument proper with detachable points, and extras comprising a needle point, a pencil point, a pen and a lengthening bar, all as shown to the left. In selection, care should be given to the workmanship; notice whether the parts fit together neatly and without lost motion, and whether the joint works tightly and yet without too great friction. A good German silver instrument, although quite expensive at the outset, will be found the cheapest in the end. A pencil point of the kind shown in our engraving is to be preferred over the old style which clamps a common pencil to the leg. The latter is not nearly so convenient and is far less accurate.

Of dividers there are two general kinds, the plain dividers, as shown in Fig. 111, and the hair-spring dividers, as shown in Fig. 112. The latter differ from the former simply in the fact of having a fine spring and a joint in one leg, the movement being controlled by the screw shown at the right. In this way, after the instrument has been set approximately to the distance desired, the adjustable leg is moved, by means of the screw, either in or out, as may be required, thus making the greatest accuracy of spacing possible. Both instruments are found desirable in an ordinary set of tools. The plain dividers will naturally be used for larger and less particular work, while the hair-spring dividers will be used in the finer parts. It frequently happens that two pairs of dividers, set to different spaces, are convenient to have at the same time.

A pair of spacers, shown in Fig. 113, is almost

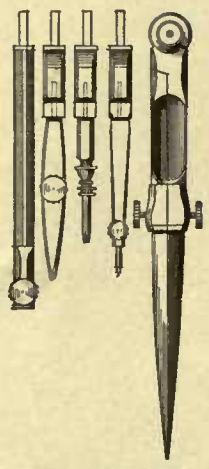

Fig. 110.—Compasses with Interchangeable Parts.

Fig. 111.—Plain Dividers.

Fig. 112.—Hair-Spring Dividers.

Fig. 113.—Steel Spring Spacers.

indispensable in a pattern cutter's outfit. He will find advantageous use for this tool, even though possessing both pairs of dividers described above. In size they are made less than that of the dividers. The points should be needle-like in their fineness, and should be capable of adjustment to within a very small distance of each other. It is sometimes desirable to divide a given profile into spaces of an eighth of an inch. The spacers should be capable of this, as well as adapted to spaces of three-quarters of an inch, without being too loose. As will be seen from the engraving, this instrument is arranged for minute variations in adjustment.

Beam Compasses and Trammels—In Fig. 114 is shown a set of beam compasses, together with a portion of the wooden rod or beam on which they are used. The latter, as will be seen by the section drawn to one side (A), is in the shape of a T. This form has considerable strength and rigidity, while at the same time it is not clumsy or heavy. Beam compasses are provided with extra points for pencil and ink work, as shown. While the general adjustment is effected by means of the clamp against the wood, minute variations are made by the screw shifting one of the points, as shown. This instrument is quite delicate and when in good order is very accurate. It should be used only for fine work on paper and never for scribing on metal.

A coarser instrument, and one especially designed for use upon metal, is shown in Fig. 115 and is called

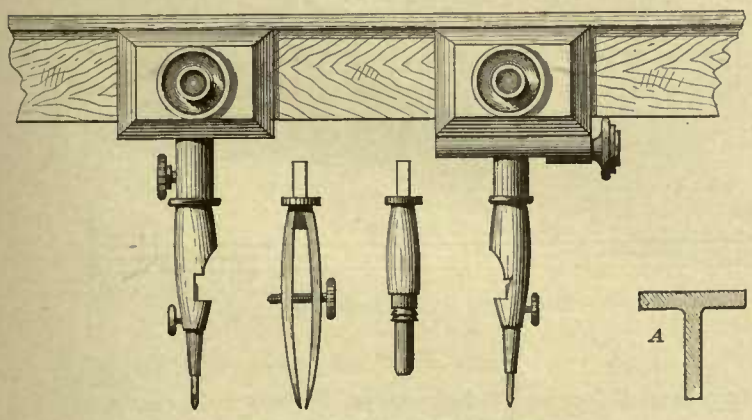

Fig. 114.—Beam Compasses.

a trammel. It is to be remarked in this connection that the name trammel, by common usage, is applied to this instrument and also to a device for drawing ellipses, which will be found described at another place. There are various forms of this instrument, all being the same in principle. The engraving shows a form in common use. A heavier stick is used with it than with the beam compasses, and no other adjustment is provided than that which is afforded by clamping against the stick. In the illustration a carrier at the

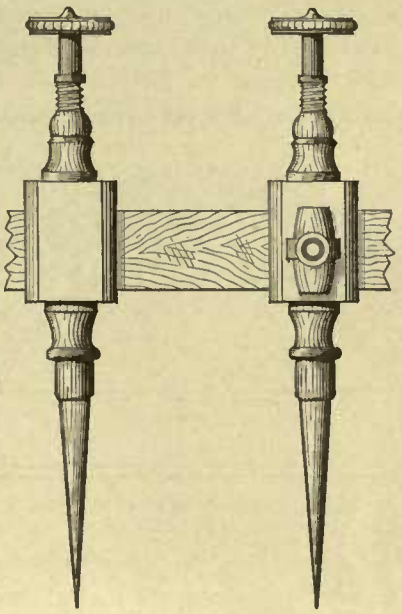

Fig. 115.—Trammel.

side is shown in which a pencil may be placed. Some trammels are arranged in such a manner that either of the points may be detached and a pencil substituted.

A trammel, by careful management, can be made to describe very accurate curves, and hence can be used in place of the beam compasses in many instances. For all coarse work it is to be preferred to the beam compasses. It is useful for all short sweeps upon sheets of metal, but for curves of a very long radius a strip of sheet iron or a piece of wire will be found of more practical service than even this tool.

The length of rods for both beam compasses and trammels, up to certain limits, is determined by the nature of the work to be done. The extreme length is determined by the strength and rigidity of the rod itself. It is usually convenient to have two rods for each instrument, one about 3½ or 4 feet in length and the other considerably longer—as long as the strength of material will admit. In the case of the trammel, by means of a simple clamping device, or, in lieu of better, by use of common wrapping twine, the rods may be spliced when unusual length is required; but a strip of sheet iron or a piece of fine wire forms a better radius, under such circumstances, than the rod.

The Protractor is an instrument for laying down and measuring angles upon paper. The instrument consists of a semicirele of thin metal or horn, as represented in Fig. 116, the circumference of whieh is divided into 180 equal parts or degrees. The principles upon which the protractor is eonstructed and used are clearly explained in the chapter on Terms and Definitions (Def. 68 "Degree"). The methods of employing it in the construetion of geometrical figures are shown

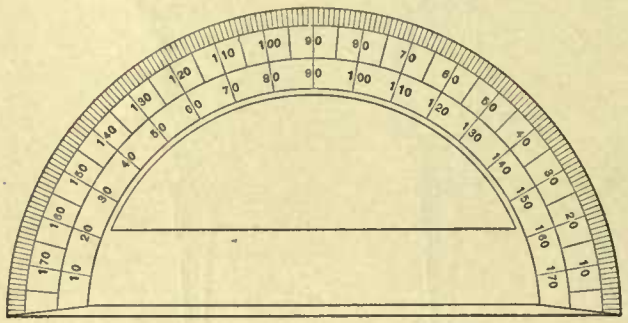

Fig. 116.—Semicircular Protractor.

in Chapter IV among the problems. For purposes of aecuracy, a large protractor is to be preferred to a small size, because in the former fractions of a degree are indieated.

While a number of geometrical problems are conveniently solved by the use of this instrument, it is not one that is specially adapted to the pattern cutter's use. All the problems whieh are solved by it can be worked out by other accurate and expeditious methods, which, in most cases, are preferable. It is one of the instruments, however, included in almost every case of instruments sold, and the student will find it advantageous to become thoroughly familiar with it, whether in practice he employs it or not.

Besides the semicircular form of the protractor shown, corresponding lines and divisions to those upon it are sometimes put upon some of the varieties of scales in use, as shown in Fig. 120.

Scales.—Many of the drawings from which the pattern cutter works—that is, from which he gets dimensions, etc.,—are what are called scale drawings, being some specified fraction of the full size of the object represented. Architects' elevations and floor plans are very generally made either $\frac{1}{8}$ or $\frac{1}{4}$ inch to the foot, or, in other words, $\frac{1}{96}$ or $\frac{1}{48}$ full size. Scale details are also employed quite extensively by architects, scales in very common use for the purpose being $1\frac{1}{2}$ inches to the foot and 3 inches to the foot, or, in other words, $\frac{1}{8}$ and $\frac{1}{4}$ full size respectively. It is essential that the pattern cutter should be familiar with the various scales in common use, that he may be able to work from any of them on demand. Several of the scales are easily read by means of the common rule, as, for example, 3 inches to the foot, in which each quarter inch on the rule becomes one inch of the scale; also, $1\frac{1}{2}$ inches to the foot, in which each eighth of an inch on the rule becomes an inch of the scale; and, likewise, $\frac{3}{4}$ inch to the foot, in whieh each sixteenth of an inch on the rule beeomes an inch of the scale. However, other scales besides these are occasionally required, which are not easily read from the common rule, and sometimes special scales are used, which are not shown on the instruments, especially calculated for the purpose. Accordingly, it is sometimes necessary for the pattern cutter to construct his own scale.

The method of constructing a scale of 1 inch to the foot is illustrated in Fig. 117, in which the divisions are made by feet, inches and half inches. In construeting sueh scales, it is usual to set off the divisions representing feet in one direction (say to the right) from a point marked 0, while the divisions for inches and fractions thereof are set off the opposite way (or to the left from 0) as shown in the illustration. In using the scale, measurements are made by placing one point of the dividers at the number of feet required; the other point can then be moved to the other side of the 0 to the required number of inches, thus embracing the entire number of feet and inches between the points of the dividers.

Besides scales of the kind just described, which

Fig. 117.—Plain Scale (1 inch to the Foot)

are termed plain divided scales, there are in common use what are known as diagonal seales, an illustration of one of which is shown in Fig. 118. The seale represented is that of $1\frac{1}{2}$ inches to the foot. The left-hand unit of division has been divided by means of the vertieal lines into 12 equal parts, representing inches. In width the scale is divided into 8 equal parts by means of the parallel lines running its entire length. Next the diagonal lines are drawn, as shown.

By a moment's inspection it will be seen that, by means of these diagonal lines, one-eighth of an inch and multiples thereof are shown on the several horizontal lines. A distance equal to the space from A to B, as marked on the scale, is read (first at the right for feet) 2 feet (then to the left for inches by means of the vertical lines figured both at top and bottom) 6 inches (and last by means of the diagonal line, figured at the end of the scale, for fractions) and three-eighths. The top and bottom lines of the scale measure feet and inches only. The other horizontal lines measure feet, inches and fractions of an inch, each horizontal line having its own particular fraction, as shown. Such scales are frequently quite useful, as greater accuracy is obtained and, as the reader will see, may be constructed by any one to any unit of measurement, and divided by the number of horizontal lines into any desired fractions.

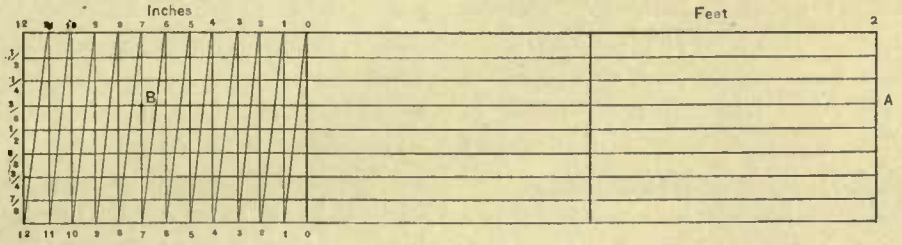

Fig. 118.—Diagonal Scale (1½ inches to the foot).

A scale in common use, and known as the triangular scale, is shown in Fig. 119. The shape of this scale, which is indicated by the name, and which is also shown in the cut, presents three sides for division. By dividing each of these through the center lengthways by a groove, as shown, six spaces for divisions are obtained, and by running the scales in pairs—that is, taking two scales, one of which is twice the size of the other, and commencing with the unit at opposite ends—the number of scales which may be put upon one of these instruments is increased to twelve. This article, which may be had in either boxwood, ivory or plated metal, and of 6, 12, 18 or 24 inches in length, is probably the most desirable for general use of any sold.

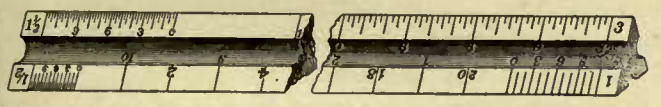

Fig. 119.—Triangular Boxwood Scale.

A flat scale is also manufactured in both boxwood and ivory. Fewer scales or divisions can be put upon it than upon the triangular scale, yet for certain purposes it is to be preferred to the latter. There are less divisions to perplex the eye in hunting out just what is required, and accordingly, there is less liability to error in its use. However, the limited number of scales which it contains greatly restricts its usefulness.

Fig. 120 shows another form of the flat scale, in quite common use in the past, but now virtually discarded in favor of more convenient dimensions and shapes. This scale combines with the various divisions of an inch the divisions of the protractor, as shown around the margin. The fact that the divisions of an inch for purposes of a scale are located in the middle of the instrument, away from the edge, which makes it necessary to take off all measurement with the dividers, renders the article awkward for use, and the arrangement of the divisions of the circle, on the margins, is less satisfactory for use than the circular protractor.

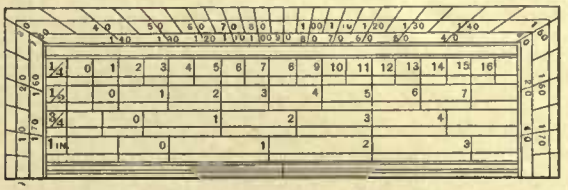

Fig. 120.—Flat Scale with Divisions of the Protractor on the Margins.

Lead Pencils.—Various qualities of pencils are sold, some at much lower prices than others, but, all things considered, in this as in other cases, the best are the cheapest. The leading brands are made in two grades or qualities. The ordinary grades employ numbers, 1, 2, 3, etc., to indicate hardness of lead, No. 1 being the softest, and No. 5 being the hardest in common use. A finer grade of pencils, known as poligrades, is marked by letters, commencing at the softest with B B,

and ending at the hardest with H H H H H H H, while other makes of pencils are marked by systems peculiar to their manufacturer. The draftsman has the choice of round or hexagon shape in all except the finest grades, the latter being made exclusively hexagon. Whatever kind of pencil the draftsman or mechanic uses, he will require different numbers for different purposes. For working drawings, full-sized details, etc., on manila paper, a No. 3 (or F) is quite satisfactory. Some like a little harder lead, and therefore prefer a No. 4 (or H). For lettering and writing in connection with drawings upon manila or ordinary detail paper, a No. 2 (H B) is usually chosen. For fine lines, as in developing a miter, in which the greatest possible accuracy is required, a No. 5 is very generally used, although many pattern cutters prefer the finer grade for this purpose and use a H H H H H.

The quality and accuracy of drawings depend, in a considerable measure, upon the manner in which pencils are sharpened. A pencil used for making fine

Fig. 121.—Two Views of Pencil Sharpened to a Chisel Point.

straight lines, as, for instance, in the various operations of pattern cutting, should be sharpened to a chisel point, as illustrated in Fig. 121. Pencils for general work away from the edges of the T-square, triangle, etc., should be sharpened to a round point, as shown in Fig. 122. It facilitates work and it is quite economical to have several pencils at command, sharpened in different ways for different purposes. Where for any reason only one pencil of a kind can be had, both ends may be sharpened, one to a chisel point and the other to a round point.

For keeping a good point upon a pencil, a piece of fine sand paper or emery paper, glued upon a piece of wood, will be found very serviceable. A flat file, mill-saw cut, is also useful for the same purpose. Sharpen the pencil with a knife, so far as the wood part is concerned, and then shape the lead as required upon the file or sand paper.

Drawing Pens.—Although most of the pattern cutter's work is done with the pencil, there occasionally arise circumstances under which the use of ink is desirable. Tracings of parts of drawings are frequently required which can be better made with ink than with pencil.

The drawing pen or ruling pen, as illustrated in Fig. 123, is used for drawing straight lines. The drawing pen, whether as a separate instrument or as an attachment to compasses or beam compasses for drawing curved lines, consists of two blades with steel points, fixed to a handle. The blades are so curved that a sufficient cavity is left between them for ink when the points meet close together or nearly so. The space between the points is regulated by means of the screw shown in the engraving, so as to draw lines of any required thickness. One of the blades is provided with a joint, so that, by taking out the screw, the blades may be completely opened and the points readily cleaned after use. The ink is put between the blades with a common pen, or sometimes by a small hair brush. In using the drawing pen it should be slightly inclined in the direction of the line to be drawn, and should be kept uniformly close to the ruler or straight-

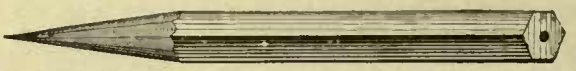

Fig. 122.—Pencil Sharpened to a Round Point.

Fig. 123.—Ruling Pen.

edge during the whole operation of drawing a line, but not so close as to prevent both points from touching the paper equally.

Keeping the blades of the pen clean is essential to good work. If the draftsman is careless in this particular, the ink will soon corrode the points to such an extent that it will be impossible to draw fine lines.

Pens will gradually wear away, and in course of time they require dressing. To dress up the tips of the blades of a pen, since they are generally worn unequally by customary usage, is a matter of some nicety. A small oil stone is most convenient for use in the operation. The points should be screwed into contact in the first place, and passed along the stone, turning upon the point in a directly perpendicular plane until they acquire an identical profile. Next they are to be unscrewed and examined to ascertain the parts of unequal thickness around the nib. The blades are then to be laid separately upon their backs upon the stone, and rubbed down at the points until they are brought up to an edge of uniform fineness. It is well to screw them together again and pass them over the

stone once or twice more to bring up any fault and to retouch them also at the outer and inner side of each blade to remove barbs or frazing, and finally to draw them across the palm of the hand.

India Ink.—For tracings, and for some kinds of drawings, which the pattern cutter is obliged to make occasionally, India ink is much better than the pencil, which is used for the greater part of his work. Care is to be exercised in the selection of ink, as poor grades are sold as well as good ones. Some little skill is required in dissolving or mixing it for use.

India ink is sold in cakes or sticks, of a variety of shapes. It is prepared for use by rubbing the end of the stick upon the surface of a ground glass, or of a porcelain slab or dish, in a very small quantity of water, until the mixture is sufficiently thick to produce a black line as it flows from the point of the ruling pen. The quality of ink may generally be determined by the price. The common size sticks are about 3 inches long. Inferior grades can be bought as low as 40 cents per stick, while a good quality is worth $1.50 to $2 per stick, and the very best is still higher. However, except in the hands of a responsible and experienced dealer, this method of judging is hardly satisfactory. To a certain extent ink may be judged by the brands upon it, although in the case of the higher qualities the brands frequently change, so that this test may not be infallible. The quality of India ink is quite apparent the moment it is used. The best is entirely free from grit and sediment, is not musky, and has a soft feel when wetted and smoothed. The color of the lines may also be used as a test of quality. With a poor ink it is impossible to make a black line. It will be brown or irregular in color and will present an irregular edge, as though broken or ragged, while an ink of satisfactory quality will produce a clean line, whether drawn very fine or quite coarse.

Various shaped cups, slabs and dishes are in use for mixing and containing India ink. In many respects they are like those used for mixing and holding water colors. Indeed, in many cases the same articles are employed. The engraving (Fig. 124) shows what is termed an India ink slab, with three holes and one slant. This article is in common use among draftsmen and serves a satisfactory purpose. In order to retard evaporation, a kind of saucers, in sets, is frequently used, so constructed that one piece will form a cover to the other, and which are known in the trade as cabinet sets or cabinet saucers. They are from 2½ to 3½ inches in diameter and come in sets of six. In the absence of ware especially designed for the purpose, India ink can be satisfactorily mixed in and used from an ordinary saucer or plate of small size. The articles made especially for it, however, are convenient, and

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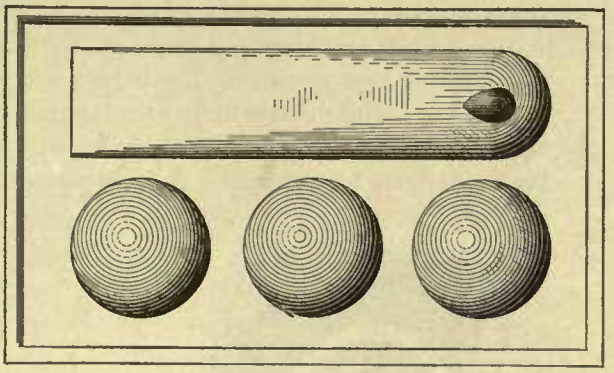

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Fig. 124.—India Ink Slab.

in facilitating the care and economical use of the ink are well worth the small price they cost.

Several makes of liquid drawing ink are also to be had, which possess the advantage of being always ready for use, thus doing away with the rubbing process. The ink costs about 25 cents a bottle, keeps well, and will answer almost every purpose quite as well as the stick ink.

Thumb Tacks or **Drawing Pins,** both names being in common use, are made of a variety of sizes, ranging from those with heads one-quarter of an inch in diam-

Fig. 125.—Thumb Tacks, or Drawing Pins.

eter up to eleven-sixteenths of an inch in diameter. They are likewise to be had of various grades and qualities. The best for general use are those of German silver, about three-eighths to five-eighths of an inch in diameter, and with steel points screwed in and riveted Those which have the points riveted only are of the second quality. The heads should be flat, to allow the T-square to pass over them readily. In the

annexed cut, Fig. 125, are shown an assortment of kinds and sizes. Those which are beveled upon their upper edges are preferable to those which are beveled underneath.

A Box of Instruments.—Fig. 126 shows a box of instruments of medium grade, as made up and sold by the trade generally. While it contains some pieces that the pattern cutter has no use for, it also contains the principal tools he requires, all put together in compact shape, and in a convenient manner for keeping the instruments clean and in good order. The tray of the box lifts out, there being a space underneath it in which may be placed odd tools, pencils, etc. Tools may be selected, as required, of most of the large dealers in drawing instruments. It will be found advantageous to the pattern cutter to buy his instruments singly as he requires them, as by so doing he will get only what he requires for use, and will probably secure

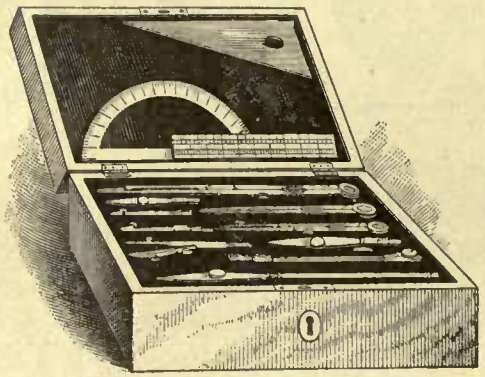


Fig. 126.—A Box of Instruments.

a better quality in the tools. After he has made his selection, a box properly fitted and lined should be provided for them and can be obtained at a small cost, or made if desirable.

India Rubber.—A good rubber with which to erase erroneous lines is indispensable in the pattern cutter's outfit. The several pencil manufacturers have put their brands upon rubber as well as upon pencils, and satisfactory quality can be had from any of them. The shape is somewhat a matter of choice, flat cakes being the most used. A very soft rubber is not so well adapted to erasing on detail paper as the harder varieties, but is to be preferred for use in fine drawings on good quality paper.

Paper.—The principal paper that the pattern cutter has anything to do with is known as brown detail paper, or manila detail paper. It can be bought of almost any width, from 30 inches up to 54 inches, in rolls of 50 to 100 pounds each. It is ordinarily sold in the roll by the pound, but can be bought at retail by the yard, although at a higher figure. There are different thicknesses of the same quality. Some dealers indicate them by arbitrary marks, as XX, XXX, XXXX; others by numbers 1, 2, 3; and still others as thin, medium and thick. The most desirable paper for the pattern cutter's use is one which combines several good qualities. It should be just as thin as is consistent with strength. A thick paper, like a stiff card, breaks when folded or bent short, and is, therefore, objectionable. The paper should be very strong and tough, as the requirements in use are quite severe. The surface should be very even and smooth, yet not so glossy as to be unsuited to the use of hard pencils. It should be hard rather than soft and should be of such a texture as to withstand repeated erasures in the same spot without damage to the surface.

White drawing paper, which the pattern cutter has occasionally to use in connection with his work, can be had of almost every conceivable grade and in a variety of sizes. The very best quality, and the kinds suited for the finest drawings, come in sheets exclusively, although the cheaper kinds are also made in the shape of sheets as well as in rolls. White drawing paper in rolls can be bought of different widths, ranging from 36 to 54 inches, and from a very thin grade up to a very heavy article, and of various surfaces. It is sold by the pound, in rolls ranging from 30 to 40 pounds each, and also at retail by the yard. A kind known as eggshell is generally preferred by architectural draftsmen.

Drawing paper in sheets is sold by the quire, and at retail by the single sheet. The sizes are generally indicated by names which have been applied to them. The following are some of the terms in common use, with the dimensions which they represent placed opposite:

Cap	13 x 17	Elephant	23 x 28
Demy	15 x 20	Atlas	26 x 34
Medium	17 x 22	Columbier	23 x 35
Royal	19 x 24	Double Elephant	27 x 40
Super Royal	19 x 27	Antiquarian	31 x 53
Imperial	22 x 30	Emperor	48 x 68

Still another set of terms is used in designating French drawing papers. Different qualities of paper, both as regards thickness, texture and surface, can be had of any of the sizes above named.

Tracing Paper and Tracing Cloth.—The pattern cutter has frequent use for tracing paper, and a good article, which combines strength, transparency and suitable surface, is very desirable. Tracing paper is sold both in sheets, in size to correspond to the drawing papers above described, and in rolls, to correspond in width to the roll drawing paper. It is usually priced by the quire and by the roll, although single sheets or single yards are to be obtained at retail. The rolls, according to the kinds, contain from 20 to 30 yards. There are various manufacturers of this article, but it is usually sold upon its merits, rather than by any brand or trade-mark. Tracing cloth, or tracing linen, is used in place of tracing paper where great strength and durability are required. This article comes exclusively in rolls, ranging in width from 18 to 42 inches. There are generally 24 yards to the roll, and prices are made according to the width, or, in other words, according to the superficial contents of the roll. Two grades are usually sold, the first being glazed on both sides and suitable only for ink work, and the second on but one side, the other being left dull, rendering it suitable for pencil marks. Upon general principles, pencil marks are not satisfactory upon cloth, even upon the quality specially prepared with reference to them. It is but a very little more labor or expense to use ink, and a much more presentable and usable drawing is made. Tracing paper may be used satisfactorily with either pencil or pen.

CHAPTER III.

Linear Drawing.

In the production of all great constructive works the drawing plays a most important part. If a piece of machinery, a ship, an aqueduct or a temple is to be built, verbal descriptions would be insufficient directions to the workmen who are to perform the actual labor; drawings become a necessity, because a drawing tells exactly what is meant, where words would utterly fail. Therefore, to everybody connected with the constructive trades, to artisans in whatever field, the ability to read, if not to make, a drawing becomes a necessity; and to those in positions of authority the ability to make a drawing is the power to convey their ideas to others. That branch of drawing with which the pattern cutter has to deal is of a purely geometrical nature and is properly termed *orthographic projection*. The term orthographic (signifying right line) is well applied because it exactly describes the nature of the work, as will be seen further on.

The geometrical drawings made use of in representing any constructive work, whether to a large or a small scale, are of three kinds—viz.: ELEVATIONS, SECTIONS and PLANS. The term *diagram* is sometimes used in connection with this class of drawing, but is not of a specific nature. It means a drawing of the simplest possible character, usually made to demonstrate a principle, and may partake of the properties of either of the above named drawings.

An **elevation,** if the word were judged by its common meaning, would be understood to show the hight of anything. It does this and more. It gives all the vertical and horizontal measurements which appear in the *front*, *side* or *end* which it represents. An elevation supposes the observer to be opposite to and on a level with all points at the same time, and is therefore an impossible view, according to the rules of pictorial art. Being always drawn to scale (including full size), it gives exact dimensions of hight and breadth at any part of the view, but furnishes no view of horizontal surfaces and no means of measuring distances to and from the observer, or in any oblique horizontal direction. An elevation may be called *front*, *side*, *end* or *rear*, according to the relative dimensions of the object, one of whose faces it represents. Any elevation or vertical section gives two sets of dimensions—*i. e.*, hight and horizontal distance, which lie parallel to the face which it shows.

A **section,** as the word indicates, is a view of a cut or a view of what remains after certain portions have been cut away for the purpose of showing more clearly the interior construction. The idea of a vertical section can best be described by supposing that a wire stretched taut, or any perfectly straight blade, was passed vertically down through an object at a given distance from one of its ends or sides, indicated by a line in some other view or views, and the portion not wanted was removed. The view made of the section may properly include only the parts cut, or if made to include or show portions that would naturally appear by the removal of the parts, it would properly be called a *sectional elevation*. Sections may also be taken horizontally at any hight above the base or ground line, indicated by a line for that purpose upon one or more of the elevations.

Horizontal sections are properly classed with plans. *Vertical sections* are known as *longitudinal* or *transverse*, according as they are taken through the long way of, or across, an object. Elevations or sections may also be constructed upon *oblique* planes when necessary to more fully show construction.

Sections of small portions or members drawn to a large scale or full size are called *profiles*. They are applied to continuous forms, as moldings, jambs, etc., and are drawn for the purpose of showing the peculiarities in form of the parts which they represent.

The view which gives all the horizontal distances in whatever direction is called the **plan.** The name plan applies equally well to a horizontal section or to a top view. In the plan, as in sections and elevations,

the observer is supposed to be opposite to (*i.e.*, directly above) all points at the same time. In idea it is the same as a map, the difference between the two terms being in the amount included in the view.

In Fig. 128 is given an illustration of the various geometrical views of an object, placed in their proper relation one to another, showing the lines of projection and the lines upon which the different sections are taken. A house placed upon a base has been selected as the most suitable object for purposes of explanation in the present case. It has been shown in diagrammatic form—that is, denuded of all cornices, trimmings or projecting parts—so as to demonstrate the principles of projection in the clearest manner possible.

It rests with the designer to determine which of the views shall be drawn first, all depending upon the given facts or specifications in his possession. If a house is to be designed, it is most likely that the plan would be drawn first, as arrangement of rooms and amount of ground to be covered would be of the first importance. If a molding be the subject of the design, the profile would be the view in which to first adjust the proportion of its parts. The method of deriving the elevation from the section or obtaining any one view from one or more other views is termed *orthographic projection*, because by it a system of parallel lines is made use of for the purpose of obtaining the same hight (or width, as the case may be) in corresponding parts in the different views.

In this connection it is to be understood that each angle or limit of outline in a sectional view is the source of a right line in the elevation. In Fig. 127 is shown, at X, a sectional view or profile of a molding, which should be so drawn that all the faces or surfaces supposed to be vertical shall lie vertically on the paper; that is, parallel to the sides of the drawing board. To project an elevation, Y, from this section, place the T-square so that the blade lies horizontal—that is, crossing the board from side to side—and bring it to the various angles A, B, C, etc., of the profile, drawing a line from each. The point E, though not an angle, is the lowest visible point or limit of that member of the mold when seen from the front, and is, therefore, entitled to representation in the elevation by a line. In like manner the point D, being the upper limit of a curve, is entitled to representation, but being so situated as to be invisible when viewed from a point in front of the mold, the line is properly made dotted. The lines of projection from the section to the elevation are also shown dotted in the engraving. A vertical line terminates the elevation of the mold at the right or end nearest the section, while the absence of such a line at its left end indicates that it extends indefinitely in that direction. It would also be proper, upon that supposition, to finish the elevation at the left with a broken line.

Referring now to Fig. 128, it is most likely that the front elevation would be next drawn after the plan. For this purpose the plan should be so placed upon the board that the part representing the front should be turned toward the bottom of the board, in which position it appears to be turned toward the observer. Place the T-square so that the blade lies vertically upon the board—that is, crossing it from front to back—and bringing it to the different angles or points of the front side of the plan, draw a line vertically from each, through that portion of space upon

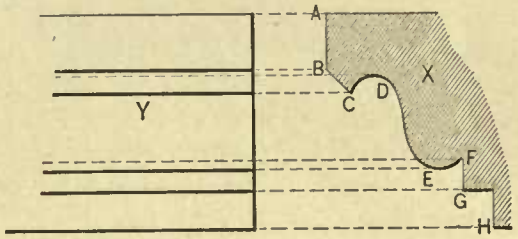


Fig. 127.—Elevation Projected from Section.

the paper allotted to the elevation, all as shown by the dotted lines. Thus each point of the elevation comes directly over the point which represents it in the plan, and the horizontal distance across any part of the new elevation thus becomes exactly the same as that of the plan. The question of hights is here a matter of design and is governed by specifications supplemented by the designer's judgment. With the plan and the front elevation complete the drawing of any other elevations or sections is entirely a matter of projection, except as new features might occur in those views which would not appear in either of the views already drawn.

If an elevation of the right side is about to be constructed, lines would be projected horizontally to the right from every point in the front elevation of the object which would be visible when seen from the right side, thus locating all the hights in the new view. As the horizontal distances in this view must agree with distances from front to back on the plan, they may best be obtained by turning the plan (or so much of it as necessary to this view) one-quarter around to the right, so

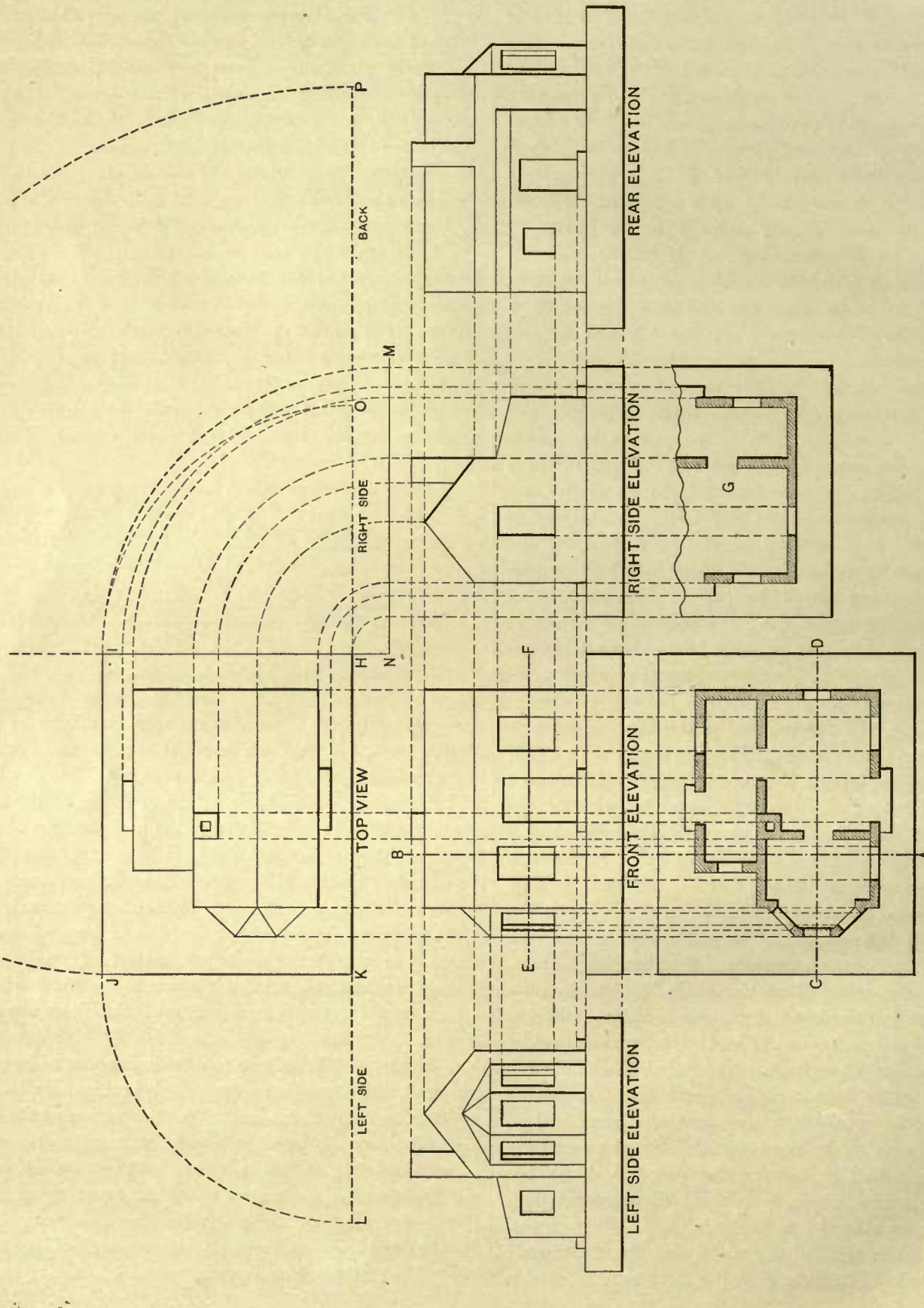


Fig. 128.—Principles of Orthographic Projection Illustrated.

that the side of which the new elevation is to be drawn will be toward the bottom or near side of the board, as shown at G; after which lines may be projected with the T-square from the points of the plan into the elevation, intersecting with corresponding lines, as shown. The same result may be accomplished by projecting the lines to the right from the side of the plan, as shown in the top view, until they reach any line parallel to the side, as H I. From this line they may be carried around a quarter circle from any convenient center, as N, arriving at a horizontal line, N M, and thence dropped downward, intersecting as before.

It will thus be seen that the elevation of the right hand side of any object comes naturally at the right of the front elevation, and the left side elevation, at its left. This idea is best illustrated by supposing that the object in question be placed in a glass box of the dimensions of the base H I J K of the top view, and that the elevation of each side of the object be projected upon the adjacent parallel side of the box at right angles to the same, and that afterward all the sides (supposing them to be hinged at the corners) be opened out into one plane, as shown by K L, H O and O P (the top face of the box being opened upward), thus displaying all the views in one plane as represented by Fig. 128.

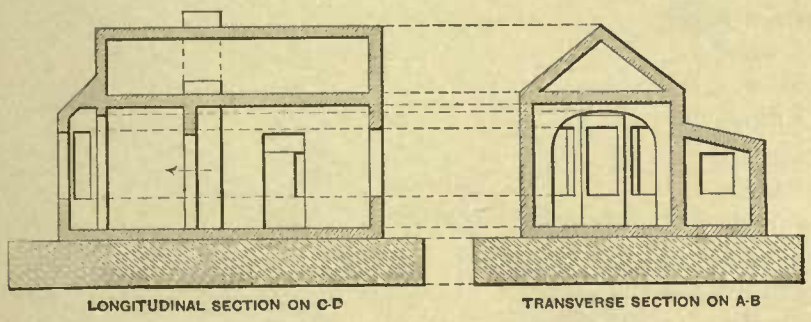


Fig. 129.—Vertical Sections Derived from Fig. 128.

This idea should not be carried so far as to open the bottom face of the box downward, because this would produce a plan as seen from below, which is never done except in the case of a design of a ceiling or soffit, when it should be spoken of as an inverted plan.

In Fig. 129 the transverse section is shown at the right of the longitudinal section, because the view in it is from the right, or in the direction of the arrow in the longitudinal section, showing what would be seen if the house were cut in two on the line A B of the plan and the right hand portion removed. The longitudinal section is for the same reason placed at the left of the transverse section—that is, it is a view from the left of the house when placed in the position shown by the transverse section. From the foregoing it is to be understood, therefore, that when a view appears to the right of another it is supposed to show what would be seen when the object is viewed from the right hand end or side of what is shown in the other, the other (or front) view being at the same time a view of the left side of what is shown by the right side elevation.

In this class of drawings various kinds of lines are used, each of which possesses a certain significance.

The general outlines of the different views should be firm and strong enough to be distinctly visible, without being so broad as to leave any doubt as to the exact dimensions of the part shown when the rule is applied for purposes of measurement.

It is not always necessary that all the lines of projection should be shown. When shown they may appear as the finest possible continuous lines, or as dotted lines such as are shown in Figs. 127, 128 and 129. Lines used in carrying points from a profile to a miter line, or from one line to another for any purpose, are really lines of projection, and for the pattern draftsman's purposes it may be said that the finer they are drawn the greater the accuracy obtained (see Chapter II under the head of Lead Pencils).

Dotted lines are also used to represent portions which are out of sight—that is, back of or underneath the other parts which constitute the view under consideration, but which it is necessary to show, as, for instance, a portion of the chimney in longitudinal section Fig. 129 and points D and F in the profile of the mold in Fig. 127.

Dotted lines are also used to show a change of position or an alternate position of some part, as, for example, the lines L K and J L show that the side J K of the top view has been swung around on the point K until it occupies the position shown by L K, its extremity J traversing the line J L. When it is necessary to use two kinds of dotted lines, those used for one purpose may be made in fine or short dots, while the others may be made a series of short dashes.

Lines showing the part of a view through which a section is taken are composed of a series of dots and dashes, as shown by A B, C D, etc., in Fig. 128, and when further distinction is required may be made by two dots alternating with a short or long dash.

When it is desirable to omit the drawing of a considerable portion of any view it is customary to terminate the incomplete side of such view by an irregular line, as shown above the plan G in Fig. 128.

It is customary in all sectional views for the parts which are represented as being cut to be ruled or lined with lines running in an *oblique* direction, as in Fig. 129. When the section comprises several different pieces lying adjacent to one another, each different part should be lined in a different direction. This ruling is understood to mean solidity. In Fig. 129 the walls and base in the different sections are represented as though made of some solid material, as wood or stone, and ruled accordingly. Where it is necessary to represent different kinds of material in the same section, different systems or kinds of lines may be used for the purpose. Thus solid and dotted lines may be used alternately, as in the base. Coarse and fine ruling, or stippling, may also be employed, according to the size of the part, or very small parts may be shown solid black, as window weights, piping or hinges. A heavy line is the only way that a thickness of metal can properly be shown in a section. In the case of a sectional view of a cornice or molding where nothing but the sheet iron appears, it is customary to make use of section lines close to the metal surface, but not to extend them clear across the space which should be filled if the moldings were of stone or other solid material. By this means a section may be distinguished from what might otherwise be taken for an elevation of a return.

In the case of elaborate drawings prepared by an architect color is frequently resorted to as a means of showing the different materials as they appear in the sectional view, yellow or differing shades of brown being used for various kinds of wood, while blue is generally used for iron, gray for stone, red for brick, etc. In the case of drawings showing many different materials it is usual to place a legend in one corner of the drawing showing what each color or style of ruling indicates.

It is always advisable to keep the different views, which it is necessary to construct, separate and distinct from one another, drawing them as near together as circumstances will permit, but never allowing one view to cover any part of the space upon the paper occupied by the other view if it can be avoided. One notable exception to this rule is to be observed. It frequently occurs in drawing an elevation of a large surface, as a pediment or side of a bracket, that it is necessary to indicate that some part of it is recessed or raised, or that a certain edge is molded or chamfered, when it would not be necessary to construct an entire sectional view for this purpose alone. To this end it is customary to draw through such mold, chamfer or recess a small section, in which case, if the depression or mold runs horizontally, the section is turned to the right or left, according to convenience, or if it runs obliquely, it is turned in the direction the mold runs. In such a section the line which represents the plane surface also shows the direction of the cut across the mold or line upon which the section is taken. In Fig. 130 is shown an elevation of a portion of a pediment, in which a small section, A B C, is introduced to show the profiles of the moldings. The line B C, which

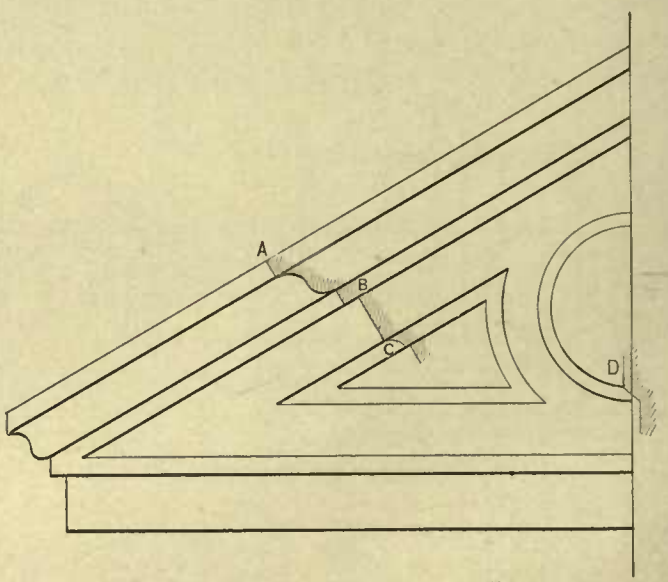


Fig. 130.—Elevation with Section of Parts.

represents the profile of the stile around the panel, shows the line upon which, or the direction in which, the section is taken, said section being turned upon this line obliquely to the left. It is necessary to rule or line this section, the ruling being kept close to and *inside* the outline or profile. By placing the ruling inside the profile no doubt can exist as to which parts are raised and which are depressed, for if at D the ruling were upon the other side of the line from that shown the section D would indicate a depressed panel instead of a raised one.

In the solution of the class of problems treated in Chapter VI, Section 1 (Miter Cutting), confusion often arises in the mind of the pattern cutter as to the proper position of a profile or of a miter line, which

confusion could never occur if all the necessary views were first drawn in accordance with the principles which this chapter is written to explain. A profile is always a section, and a miter line is either a part of an elevation projected from the section or part of another section bearing certain relations of hight or breadth to the first. A pattern is likewise always projected—that is, carried off by right lines—from an elevation or plan the same as an elevation is projected from a section.

It should also be remembered in this connection that the operation of developing a pattern is not completed until its entire outline is drawn. The line forming its termination at the end opposite the miter cut, although simply a straight line, is properly derived from the elevation or plan used, the same as all points and other lines of the pattern.

Much trouble is experienced through lack of knowledge of the principles of Linear Drawing, which if thoroughly understood could never result in such mistakes as producing a face miter where a return was intended or using the piece of metal from the wrong side of the miter cut.

Too much emphasis cannot be placed upon the importance of thoroughly understanding the subject treated in this chapter, as such a knowledge comprehends within itself an answer to the many questions continually arising in the course of the pattern draftsman's labors.

CHAPTER IV.

Geometrical Problems.

In presenting this chapter to the student no attempt has been made to give a complete list of geometrical problems, but all those have been selected which can be of any assistance to the pattern draftsman, and especial attention has been given in their solution to those methods most adaptable to his wants. They are arranged as far as possible in logical order and are classified under various sub-heads in such a manner that the reader will have no difficulty in finding what he wishes by simply looking through the pages, the diagrams given with each being sufficient to indicate the nature of the problem and, as it were, form a sort of index.

1. To Draw a Straight Line Parallel to a Given Line and at a Given Distance from it, Using the Compasses and Straight-Edge.—In Fig. 131, let C D be the given line parallel to which it is desired to draw another straight line. Take any two points, as A and B, in the given line as centers, and, with a radius equal to the given distance, describe the arcs $x\ x$ and $y\ y$. Draw a line touching these arcs, as shown at E F. Then E F will be parallel to C D.

2. To Draw a Line Parallel to Another by the Use of Triangles or Set-Squares.—In Fig. 132, let A B be the line parallel to which it is desired to draw another. Place one side of a triangle or set-square, F^1, against it, as indicated by the dotted lines. While holding F^1 firmly in this position, bring a second triangle, or any straight edge, E, against one of its other sides, as shown. Then, holding the second triangle firmly in place, slide the first away from the given line, keeping the edges of the two triangles in contact, as shown in the figure. Against the same edge of the first triangle that was placed against the given line draw a second line, as shown by C D. Then C D will be parallel to A B. In drawing parallel lines by this method it is found advantageous to place the longest edges of the triangles against each other, and to so place the two instruments that the movement of one triangle against the other shall be in a direction oblique to the lines to be drawn, as greater accuracy is attainable in this way.

3. To Erect a Perpendicular at a Given Point in a Straight Line by Means of the Compasses and Straight-Edge.—In Fig. 133, let A B represent the given straight line, at the point C in which it is required to erect a perpendicular. From C as a center with any convenient radius strike small arcs cutting A B, as shown by D and B. With D and B as centers, and with any radius longer than the distance from each of these points to C, strike arcs, as shown by $x\ x$ and $y\ y$. From the point at which these arcs intersect, E, draw a line to the point C, as shown. Then E C will be perpendicular to A B.

4. To Erect a Perpendicular at or near the End of a Given Straight Line by Means of the Compasses and Straight-Edge.—First Method.—In Fig. 134, let A B be the given straight line, to which, at the point P, situated near the end, it is required to erect a perpendicular. Take any point (C) outside of the line A B. With C as center, and with a radius equal to the distance from C to P, strike the arc, as shown, cutting the given line A B in the point P, continuing it till it also cuts in another point, as at E. From E, through the center, C, draw the line E F, cutting the arc, as shown at F. Then from the point F, thus determined, draw a line to P, as shown. The line F P is perpendicular to A B.

5. To Erect a Perpendicular at or near the End of a Given Straight Line by Means of the Compasses and Straight-Edge.—Second Method.—In Fig. 135, let B A be the given straight line, to which, at the point P, it is required to erect a perpendicular. From the point P, with a radius equal to three parts, by any scale, describe an arc, as indicated by $x\ x$. From the same point, with a radius equal to four parts, cut the line B A in the point C. From the point C, with a radius equal to five parts, intersect the arc first drawn by the

arc *y y*. From the point of intersection D draw the line D P. Then D P will be perpendicular to B A.

6. To Draw a Line Perpendicular to Another Line by the Use of Triangles or Set Squares.—In Fig. 136, let C D be the given line, perpendicular to which it is required to draw another line. Place one side of a triangle, B, against the given line, as shown. Bring another triangle, A, or any straight edge, against the long side or hypothenuse of the triangle B, as shown. Then move the triangle B along the straight edge or triangle A, as indicated by the dotted lines, until the opposite side of B crosses the line C D at the required point. When against it, draw the line E F, as shown. Then E F is perpendicular to C D. It is evident that this rule is adapted to drawing perpendiculars at any point in the given line, whether central or located near the end. Its use will be found especially convenient for erecting perpendiculars to lines which run oblique to the sides of the drawing board.

7. To Divide a Given Straight Line into Two Equal Parts, with the Compasses, by Means of Arcs.—In Fig. 137, let it be required to divide the straight line A B into two equal parts. From the extremes A and B as centers, and with any radius greater than one-half of A B, describe the arcs *d f* and *a e*, intersecting each other on opposite sides of the given line A B. A line drawn through these points of intersection, as shown by G H, will bisect the line A B, or, in other words, divide it into two equal parts.

8. To Divide a Straight Line into Two Equal Parts by the Use of a Pair of Dividers.—In Fig. 138, it is required to divide the line A B into two equal parts, or to find its middle point. Open the dividers to as near half of the given line as possible by the eye. Place one point of the dividers on one end of the line, as at A. Bring the other point of the dividers to the line, as at C, and turn on this point, carrying the first around to D. Should the point D coincide with the other end of the line, the division will be correct. But should the point D fall within (or without) the end of the line, divide this deficit (or excess) into two equal parts, as nearly as is possible by the eye, and extend (or contract) the opening of the dividers to this point and apply them again as at first. Thus, finding that the point D still falls within the end of the line, the first division is evidently too short. Therefore, divide the deficit D B by the eye, as shown by E, and increase the space of the dividers to the amount of one of D E. Then, commencing again at A, step off as before, and finding that upon turning the dividers

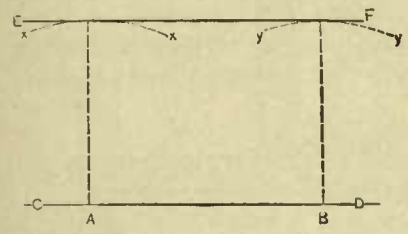


Fig. 131.—To Draw a Straight Line Parallel to a Given Straight Line, and at a Given Distance from it, Using the Compasses and a Straight-Edge.

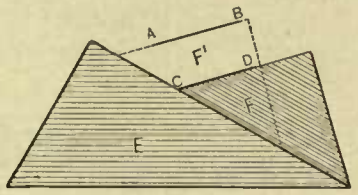


Fig. 132.—To Drow a Line Parallel to Another by the Use of Triangles or Set Squares.

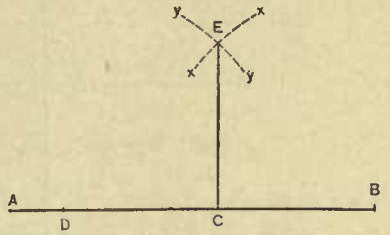


Fig. 133.—To Erect a Perpendicular at a Given Point in a Straight Line, Using the Compasses and Straight-Edge.

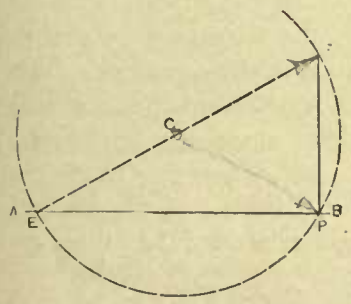


Fig. 134.—To Erect a Perpendicular at or near the End of a Given Straight Line, Using the Compasses and Straight-Edge. First Method.

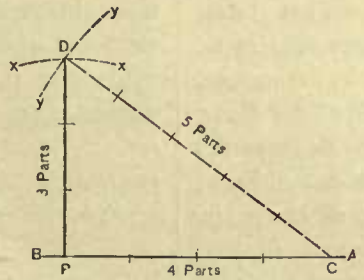


Fig. 135.—To Erect a Perpendicular at or near the End of a Given Straight Line. Second Method.

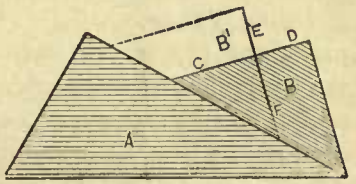


Fig. 136.—To Draw a Line Perpendicular to Another by the Use of Triangles.

upon the point F the other point coincides with the end of the line B, F is found to be the middle point in the line. In some cases it may be necessary to repeat this operation several times before the exact center is obtained.

9. To Divide a Straight Line into Two Equal Parts by the Use of a Triangle or Set Square.—In Fig. 139, let A B be a given straight line. Place a T-square

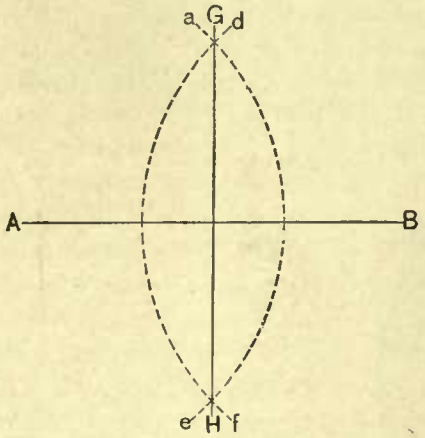


Fig. 137.—To Divide a Straight Line into Two Equal Parts by Means of Arcs.

or some straight edge parallel to A B. Then bring one of the right-angled sides of a set square against it, and slide it along until its long side, or hypothenuse, meets one end of the line, as A. Draw a line along the long side of the triangle indefinitely. Reverse the position of the set square, as shown by the dotted lines, bringing its long side against the end, B, of the given

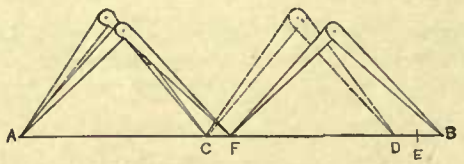


Fig. 138.—To Bisect a Straight Line by the Use of the Dividers.

straight line, and in like manner draw a line along its long side cutting the first line. Next slide the set square along until its vertical side meets the intersection of the two lines, as shown at C, from which point drop a perpendicular to the line A B, cutting it at D. Then D will be equidistant from the two extremities A and B.

10. To Divide a Given Straight Line into Any Number of Equal Parts.—In Fig. 140, let A B be a given straight line to be divided into equal parts, in this case eight. From one extremity in this line, as at A, draw a line, as either A C or A D, oblique to A B. Set the dividers to any convenient space, and step off the oblique line, as A C, eight divisions, as shown by *a b c d*, etc. From the last of the points, *h*, thus obtained, draw a line to the end of the given line, as shown by *h h²*. Parallel to this line draw other lines, from each of the other points to the given line. The divisions

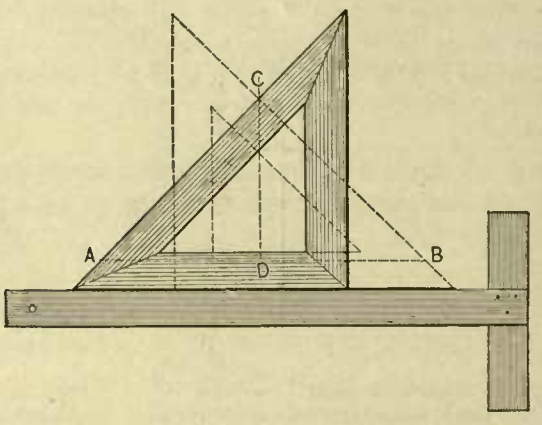


Fig. 139.—To Bisect a Straight Line by the Use of a Triangle.

thus obtained, indicated in the engraving by a^2 b^2 c^2, etc., will be the desired spaces in the given line. It is evident by this rule that it is immaterial, except as a matter of convenience, to what space the dividers are set. The object of the second oblique line in the engraving is to illustrate this. Upon A C the dividers were set so as to produce spaces shorter than those re-

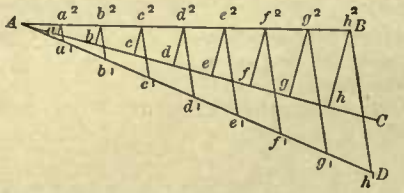


Fig. 140.—To Divide a Given Straight Line into Any Number of Equal Parts

quired in the given line A B, while in A D the spaces were made longer than those required in the given line. By connecting the last point of either line with the point B, as shown by the lines *h h²* and *h¹ h²*, and drawing lines from the points in each line parallel to these lines respectively, it will be seen that the same divisions are obtained from either oblique line.

11. To Divide a Straight Line Into Any Number of Equal Parts by Means of a Scale.—It may be more convenient to transfer the length of a given line to a slip of

paper, and by laying the paper across a scale, as shown in Fig. 141, mark the required dimensions upon it, and afterward transfer them to a given line, than to divide the line itself by one of the methods explained for that purpose. It may also occur that it is desirable to divide lines of different lengths into the same number of equal parts, or the same lengths of lines into different numbers of equal parts. Such a scale as is shown in Fig. 141 is adapted to all of these purposes. The scale may be ruled upon a piece of paper or upon a sheet of metal, as is preferred. The lines may be all of one color, or two or more colors may be alternated, in order to facilitate counting the lines or following them by the eye across the sheet. In size, the scale should be adapted to the special purposes for which it is intended to be used. By the contrast of two colors

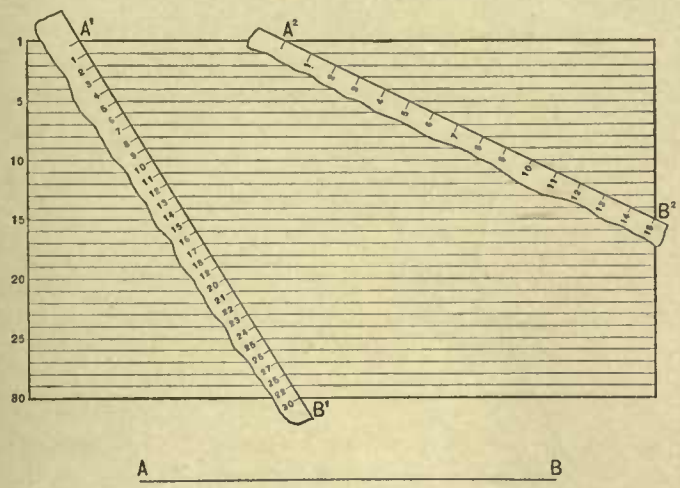


Fig. 141.—To Divide a Straight Line into Any Number of Equal Parts by Means of a Scale.

in ruling the lines, one scale may be adapted to both coarse and fine work. For instance, if the lines are ruled a quarter of an inch apart, in colors alternating red and blue, in fine work all the lines in a given space may be used, while in large work, in which the dimensions are not required to be so small, either all the red or all the blue lines may be used, to the exclusion of those of the other color. Let it be required to divide the line A B in Fig. 141 into thirty equal parts. Transfer the length A B to one edge of a slip of paper, as shown by A' B', and placing A' against the first line of the scale, carry B' to the thirtieth line. Then mark divisions upon the edge of the strip of paper opposite each of the several lines it crosses, as shown. Let it be required to divide the same length A B into fifteen equal parts by the scale. Transfer the length A B to a straight strip of paper, as before. Place A² against the first line and carry B² against the fifteenth line, as shown. Then mark divisions upon the edge of the paper opposite each line of the scale, as shown.

12. To Divide a Given Angle into Two Equal Parts.—In Fig. 142, let A C B represent any angle which it is

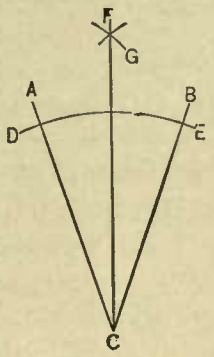


Fig. 142.—To Bisect a Given Angle.

required to bisect. From the vertex, or point C, as center, with any convenient radius, strike the arc D E, cutting the two sides of the angle. From D and E as centers, with any radius greater than one-half the length of the arc D E, strike short arcs intersecting at G, as shown. Through the point of intersection, G, draw a line to the vertex of the angle, as shown by F C. Then F C will divide the angle into two equal parts.

13. To Trisect an Angle.—No strictly geometrical method of solving this problem has ever been discovered. The following method, partly geometrical and partly mechanical, is, however, perfectly accurate and can be used to advantage whenever it becomes necessary to find an exact one-third or two-thirds of an angle:

Let A B C, Fig. 143, be the angle of which it is

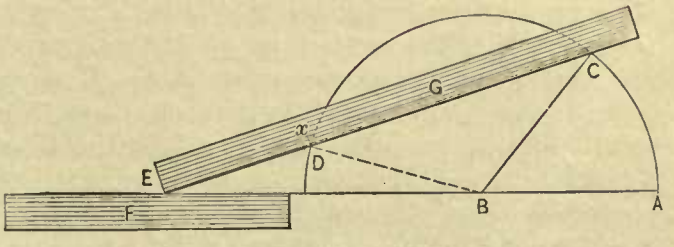


Fig. 143.—To Trisect a Given Angle.

required to find one-third. Extend one of its sides beyond the vertex indefinitely, as shown by B E, and upon this line from B as center with any convenient radius describe a semicircle A C D, cutting both sides of the angle. Place a straight edge firmly against the

extended side as at F, and a pin at the point C. On another straight edge (G) having a perfect corner at E, set off from one end a distance equal to the radius of the semicircle as shown by point x; and placing this straight edge, with the end upon which the radius was set off, against the other straight edge (F) and its edge near the other end, against the pin at the point C, all as shown, slide it along until the mark x comes to the semicircle establishing the point D. Draw the line D B, then the angle D E B will be one-third of the angle A B C, and C D B will be two-thirds of it.

14. To Find the Center from which a Given Arc is Struck.—In Fig. 144, let A B C represent the given

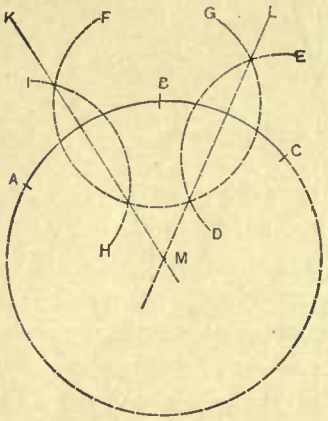


Fig. 144.—To Find the Center from which a Given Arc is Struck.

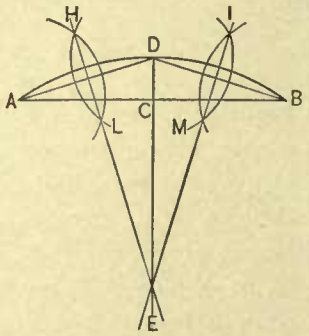


Fig. 146—The Chord and Hight of a Segment of a Circle Being Given, to find the Center from which the Arc may be Struck.

arc, the center from which it was struck being unknown and to be found. From any point near the middle of the arc, as B, with any convenient radius, strike the arc F G, as shown. Then from the points A and C, with the same radius, strike the intersecting arcs I H and E D. Through the points of intersection draw the lines K M and L M, which will meet in M. Then M is the center from which the given arc was struck. Instead of the points A and C being taken at the extremities of the arc, which would be quite inconvenient in the case of a long arc, these points may be located in any part of the arc which is most convenient. The greater the distance between A and B and B and C, the greater will be the accuracy of succeeding operations. The essential feature of this rule is to strike an arc from the middle one of the points, and then strike intersecting arcs from the other two points, using the same radius. It is not necessary that the distance from A to B and from B to C shall be exactly the same.

15. To Find the Center from which a Given Arc is Struck by the Use of the Square.—In Fig. 145, let A B C be the given arc. Establish the point B at pleasure and draw two chords, as shown by A B and B C. Bisect these chords, obtaining the points E and D. Place the square against the chord B C, as shown in the engraving, bringing the heel against the middle point, D, and scribe along the blade indefinitely. Then place the square, as shown by the dotted lines, with the heel against the middle point, E, of the second chord, and in like manner scribe along the blade, cutting the first line in the point F. Then F will be the center of the circle, of which the arc A B C

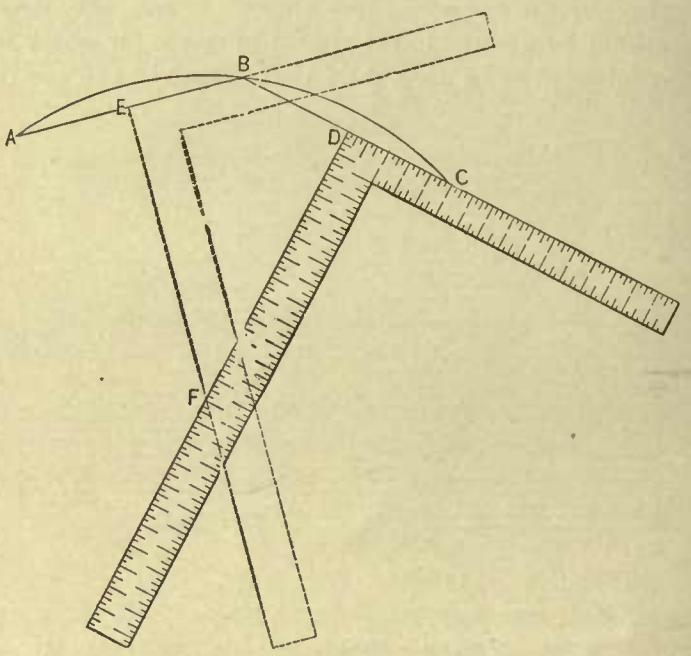


Fig. 145.—To Find the Center from which a Given Arc is Struck, by the Use of the Square.

is a part. This rule will be found very convenient for use in all cases where the radius is less than 24 inches in length.

16. The Chord and Hight of a Segment of a Circle being Given, to Find the Center from which the Arc may be Struck.—In Fig. 146, let A B represent the chord of a segment or arc of a circle, and D C the rise or hight. It is required to find a center from which an arc, if struck, will pass through the three points A, D and B. Draw A D and B D. Bisect A D, as shown, and prolong the line H L indefinitely. Bisect D B and prolong I M until it cuts H L, produced in the point E. Then E, the point of intersection, will be the center sought. It will be observed that by producing D C, and intersecting it by either H L or

I M prolonged, the same point is found. Therefore, if preferred, the bisecting of either A D or D B may be dispensed with. A practical application of this rule occurs quite frequently in cornice work, in the construction of window caps and other similar forms, to fit frames already made. In the conveying of orders from the master builder or carpenter to the cornice worker, it is quite customary to describe the shape of the head of the frames which the caps are to fit by stating that the width is, for example, 36 inches, and that the rise is 4 inches. To draw the shape thus described, proceed as follows: Set off A B equal to 36 inches, from the center of which erect a perpendicular, D C, which make equal to 4 inches. Continue D C in the direction of E indefinitely. Draw A D, which bisect, as shown, and draw H L, producing it until it cuts D C prolonged, in the point E. Then with E as center and E D as radius, strike the arc A D B.

17. To Strike an Arc of a Circle by a Triangular Guide, the Chord and Hight Being Given.—In Fig. 147, let

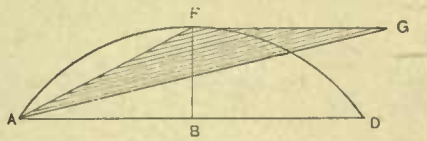


Fig. 147.—To Strike an Arc of a Circle by a Triangular Guide.

A D be the given chord and B F the given hight. The first step is to determine the shape and size of the triangular guide. Connect A and F, as shown. From F, parallel to the given chord A D, draw F G, making it in length equal to A F, or longer. Then A F G, as shown in the engraving, is the angle of the triangular guide to be used. Construct the guide of any suitable material, making the angle of two of its sides equal to the angle A F G. Drive pins at the points A, F and D. Place the guide as shown. Put a pencil at the point F. Shift the guide in such a manner that the pencil will move toward A, keeping the guide at all times against the pins A and F. Then reversing, shift the guide so that the pencil at the point F will move toward D, keeping the guide during this operation against the pins F and D. By this means the pencil will be made to describe the arc A F D. It may be interesting to know that if the angle F of the triangular guide be made a right angle, the arc described by it will be a semicircle. By these means, then, a steel square may be used in drawing circles, as illustrated in Fig. 148, the pins being placed at A, B and C.

18. To Draw a Circle Through any Three Given Points not in a Straight Line.—In Fig. 149, let A, D and E be any three given points not in a straight line, through which it is required to draw a circle. Connect the given points by drawing the lines A D and D E. Bisect the line A D by F C, drawn perpendicular to it, as shown. Also bisect D E by the line G C, as shown. Then the point C, at which these lines meet, is the center of the required circle.

19. To Erect a Perpendicular to an Arc of a Circle, without having Recourse to the Center.—In Fig. 150, let A D B be the arc of a circle to which it is required to erect a perpendicular. With A as center, and with any radius greater than half the length of the given arc, describe the arc $x\ x$, and with B as center, and with the same radius, describe the arc $y\ y$, intersecting

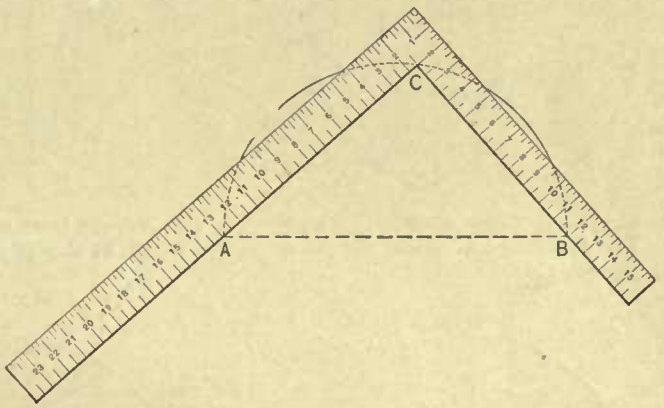


Fig. 148.—To Describe a Semicircle with a Steel Square.

the arc first struck, as shown. Through the points of intersection draw the line F E. Then F E will be perpendicular to the arc, and if sufficiently produced will reach the center from which the arc A B is drawn.

20. To Draw a Tangent to a Circle or Arc of a Circle at a given Point without having Recourse to the Center.—In Fig. 151, let A D B be the arc of a circle, to which a tangent is to be drawn at the point D. With D as center, and with any convenient radius, describe the arc A F B, cutting the given arc in the points A and B. Join the points A and B, as shown. Through D draw a straight line parallel to A B, as shown by E H, then E H will be the required tangent.

21. To Ascertain the Circumference of a Given Circle.—In Fig. 152, let A D B C be the circle, equal to the circumference of which it is required to draw a straight line. Draw any two diameters at right angles, as shown by A B and D C. Divide one of the four arcs, as, for instance, D B, into eleven equal parts, as shown.

From 9, the second of these divisions from the point B, let fall a perpendicular to A B, as shown by 9 F. To three times the diameter of the circle (A B or D C) add the length 9 F, and the result will be a very close approximation to the length of the circumference. This rule, upon a diameter of 1 foot, gives a length of about $\frac{3}{50}$ths of an inch in excess of the actual length of the circumference.

22. To Draw a Straight Line Equal in Length to the Circumference of any Circle or of any Part of a Circle — dividers are placed upon the line, no perceptible curve shall exist between them, and, beginning at one end of the curve, step to the other end of the same, or so near the end that the remaining space shall be less than that between the points of the dividers, then beginning at the end of any straight line step off upon it the same number of spaces, after which add to them the remaining small space of the curve by measurement with the dividers. This will be found the quickest and most accurate of any method for the pattern cutters' use.

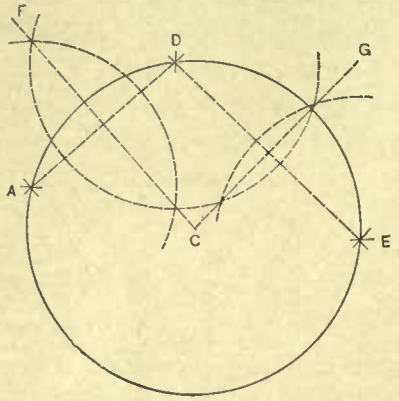


Fig. 149.—To Draw a Circle Through any Three Given Points Not in a Straight Line.

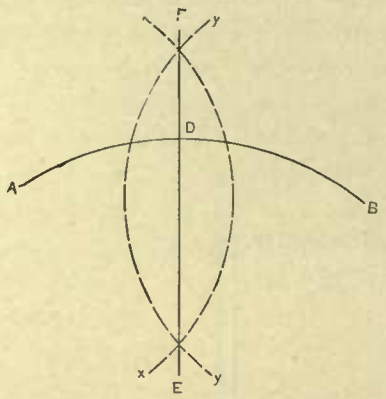


Fig. 150.—To Erect a Perpendicular to an Arc of a Circle.

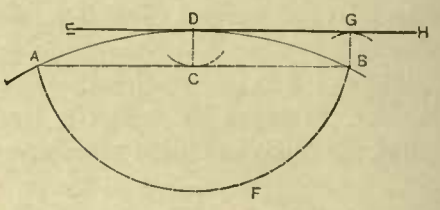


Fig. 151.—To Draw a Tangent to a Circle or Arc.

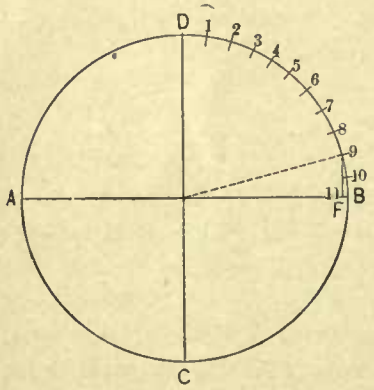


Fig. 152.—To Ascertain the Circumference of a Given Circle.

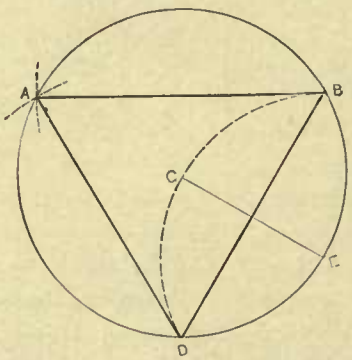


Fig. 153.—To Inscribe an Equilateral Triangle within a Given Circle.

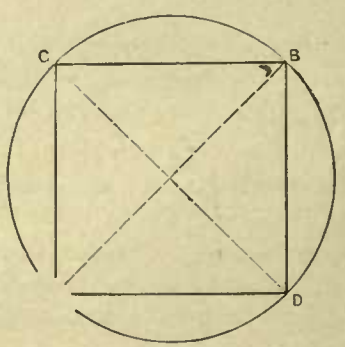


Fig. 154.—To Inscribe a Square within a Given Circle.

Various approximate rules, similar to the one given in the problem above, for performing these operations are known and sometimes used among workmen, but cannot be recommended here because in using them considerable time and trouble is required to obtain a result which is not accurate when obtained, thus rendering such methods impracticable. The simplest and most accurate method for obtaining the length of any curved line is as follows: Take between the points of the dividers a space so small that when the points of the

The most common rules in use for the construction of polygons, whether drawn within circles or erected upon given sides, are those which employ the straight-edge and compasses only. Other instruments may also be employed to great advantage, as will be shown further on, leaving the student to decide which method is the most suited to any case he may have in hand. Accordingly, the construction of polygons will be treated under three different heads arranged according to the tools employed.

THE CONSTRUCTION OF REGULAR POLYGONS.

I —BY THE USE OF COMPASSES AND STRAIGHT-EDGE.

23. To Inscribe an Equilateral Triangle within a Given Circle.—In Fig. 153, let A B D be any given circle within which an equilateral triangle is to be drawn. From any point in the circumference, as E, with a radius equal to the radius of the circle, describe the arc D C B, cutting the given circle in the points D and B. Draw the line D B, which will be one side of the required triangle. From D or B as center, and with D B as radius, cut the circumference of the given circle, as shown at A. Draw A B and A D, which will complete the figure.

24. To Inscribe a Square within a Given Circle.—In Fig. 154, let A C B D be any given circle within which it is required to draw a square. Draw any two diameters at right angles with each other, as C D and A B. Join the points C B, B D, D A and A C, which will complete the required figure.

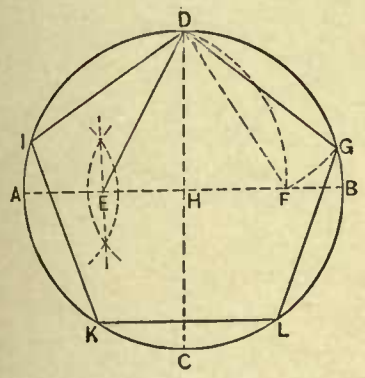


Fig. 155.—To Inscribe a Regular Pentagon within a Given Circle.

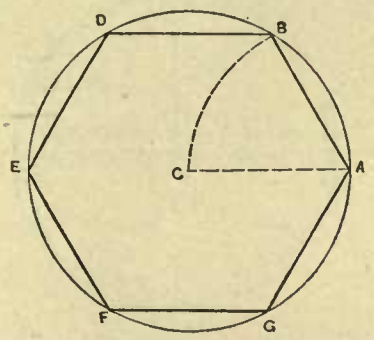


Fig. 156.—To Inscribe a Regular Hexagon within a Given Circle.

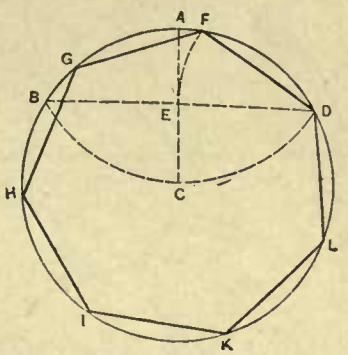


Fig. 157.—To Inscribe a Regular Heptagon within a Given Circle.

25. To Inscribe a Regular Pentagon within a Given Circle.—In Fig. 155, A D B C represents a circle in which it is required to draw a regular pentagon. Draw any two diameters at right angles to each other, as A B and D C. Bisect the radius A H, as shown at E. With E as center and E D as radius strike the arc D F, and with the chord D F as radius, from D as center, strike the arc F G, cutting the circumference of the given circle at the point G. Draw D G, which will equal one side of the required figure. With the dividers set equal to D G, step off the spaces in the circumference of the circle, as shown by the points I K and L. Draw D I, I K, K L and L G, thus completing the figure.

26. To Inscribe a Regular Hexagon within a Given Circle.—In Fig. 156, let A B D E F G be any given circle within which a hexagon is to be drawn. From any point in the circumference of the circle, as at A, with a radius equal to the radius of the circle, describe the arc C B, cutting the circumference of the circle in the point B. Connect the points A and B. Then A B will be one side of the hexagon. With the dividers set to the distance A B, step off in the circumference of the circle the points G, F, E and D. Draw the connecting lines A G, G F, F E, E D and D B, thus completing the figure. By inspection of this figure it will be noticed that the radius of a circle is equal to one side of the regular hexagon which may be inscribed within it. Therefore set the dividers to the radius of a circle and step around the circumference, connecting the points thus obtained.

27. To Inscribe a Regular Heptagon within a Given Circle.—In Fig. 157, let F A G B H I K L D be the given circle. From any point, A, in the circumference, with a radius equal to the radius of the circle, describe the arc B C D, cutting the circumference of the circle in the points B and D. Draw the chord B D. Bisect the chord B D, as shown at E. With D as center, and with D E as radius, strike the arc E F, cutting the circumference in the point F. Draw D F, which will be one side of the heptagon. With the dividers set to the distance D F, set off in the circumference of the circle the points G H I K and L, and draw the connecting lines F G, G H, H I, I K, K L and L D, thus completing the figure.

28. To Inscribe a Regular Octagon within a Given Circle.—In Fig. 158, let B I D F A G E H be the given circle within which an octagon is to be drawn. Draw any two diameters at right angles to each other,

as B A and D E. Draw the chords D A and A E. Bisect D A, as shown, and draw L H. Bisect A E and draw K I. Then connect the several points in the circumference thus obtained by drawing the lines D I, I B, B H, H E, E G, G A, A F and F D, which will complete the figure.

29. To Inscribe a Regular Nonagon within a Given Circle.—In Fig. 159, let M K F E be the given circle. Draw any two radii at right angles to each other, as B C and A C, and draw the chord B A. From A as center, and with a radius equal to one-half the chord A B, as shown by A D, strike the arc D E, cutting the circumference of the circle at the point E. Draw A E, which will be one side of the nonagon. Set the dividers to the distance A E and step off the points M, H, K, G, I, F and L, and draw the connecting lines, as shown, thus completing the figure.

Circle.—In Fig. 161, let B D A L be any given circle in which a regular figure of eleven sides is to be drawn. Draw any diameter, as B A, and draw a radius, as D C, at right angles to B A. Bisect C A, thus obtaining the point E. From E as center, and with E D as radius, describe the arc D F, cutting B A in the point F. With D as center, and D F as radius, describe the arc F G, cutting the circumference in the point G. Draw the chord G D and bisect it, as shown by H C, thus obtaining the point K. From D as center, and with D K as radius, cut the circumference in the point I. Draw I D. Then I D will be equal to one side of the required figure. Set the dividers to this space and step off the points in the circumference, as shown by N, R, S, M, P, L, O, T and V, and draw the connecting chords, as shown, thus completing the figure.

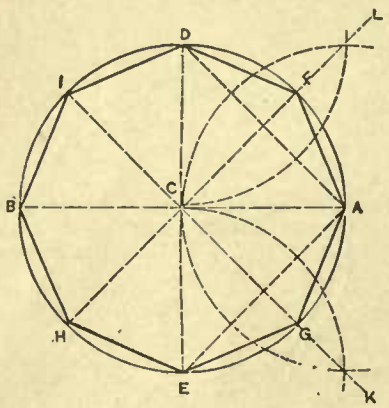


Fig. 158.—To Inscribe a Regular Octagon within a Given Circle.

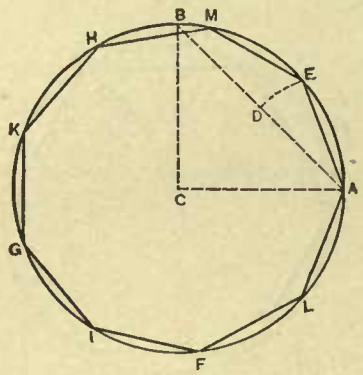


Fig. 159.—To Inscribe a Regular Nonagon within a Given Circle.

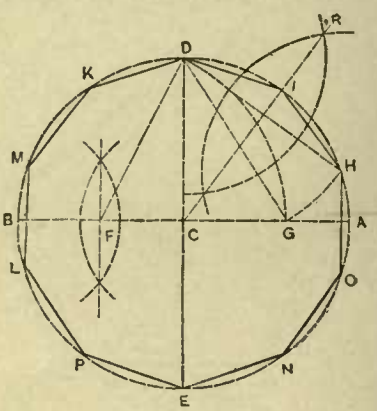


Fig. 160.—To Inscribe a Regular Decagon within a Given Circle.

30. To Inscribe a Regular Decagon within a Given Circle.—In Fig. 160, let D B E A be any given circle in which a decagon is to be drawn. Draw any two diameters through the circle at right angles to each other, as shown by B A and D E. Bisect B C, as shown at F, and draw F D. With F as center, and F D as radius, describe the arc D G, cutting B A in the point G. Draw the chord D G. With D as center, and D G as radius, strike the arc G H, cutting the circumference in the point H. Connect D and H, as shown. Bisect D H and draw the line C R, cutting the circumference in the point I. Draw the lines H I and I D, which will then be two sides of the required figure. Set the dividers to the distance H I and space off the circumference of the circle, as shown, and draw the connecting lines D K, K M, M L, L P, P E, E N, N O and O H, thus completing the figure.

31. To Inscribe a Regular Undecagon within a Given

32. To Inscribe a Regular Dodecagon within a Given Circle.—In Fig. 162, let M F A I be any given circle in which a dodecagon is to be drawn. From any point in the circumference, as A, with a radius equal to the radius of the circle, describe the arc C B, cutting the circumference in the point B. Draw the chord A B, which bisect as shown, and draw the line O C, cutting the circumference in the point D. Draw A D, which will then be one side of the given figure. With the dividers set to this space step off in the circumference the points B, I, N, H, M, G, L, F, K and E, and draw the several chords, as shown, thus completing the figure.

33. General Rule for Inscribing any Regular Polygon in a Given Circle.—Through the given circle draw any diameter. At right angles to this diameter draw a radius. Divide that radius into four equal parts, and prolong it outside the circle to a distance equal to three

of those parts. Divide the diameter of the circle into the same number of equal parts as the polygon is to have sides. Then from the end of the radius prolonged, as above described, through the second division in the diameter, draw a line cutting the circumference. Connect this point in the circumference and the nearest end of the diameter. The line thus drawn will be one side of the required figure. Set the dividers to this space and step off on the circumference of the circle outside the circle to the extent of three of those parts, as shown by *a b c*, thus obtaining the point *c*. From *c*, through the second division in the diameter, draw the line *c* H, cutting the circumference in the point H. Connect H and E. Then H E will be one side of the required figure. Set the dividers to the distance H E and step off the circumference, as shown, thus obtaining the points for the other sides, and draw the connecting arcs, all as illustrated in the figure.

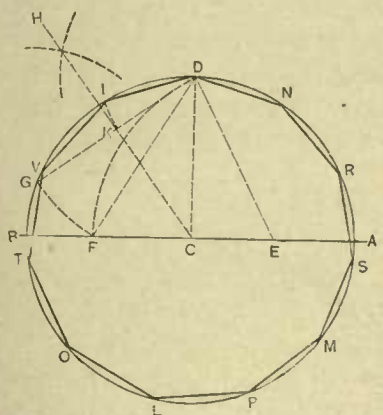


Fig. 161.—To Inscribe a Regular Undecagon within a Given Circle.

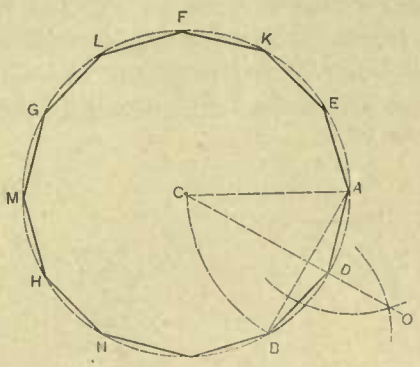


Fig. 162.—To Inscribe a Regular Dodecagon within a Given Circle.

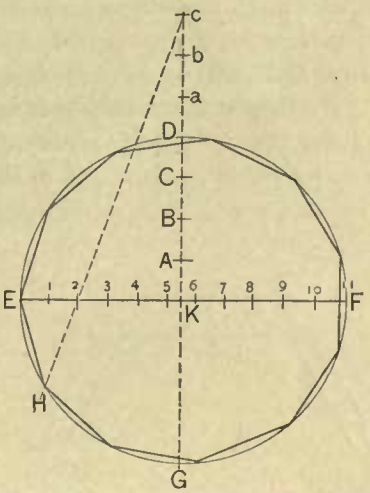


Fig. 163.—To Inscribe a Regular Undecagon within a Given Circle by the General Rule.

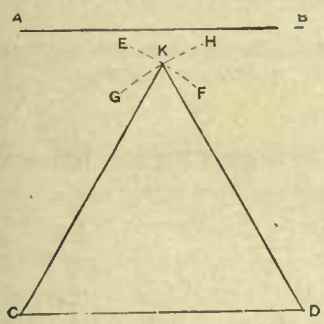


Fig. 164.—Upon a Given Side to Construct an Equilateral Triangle.

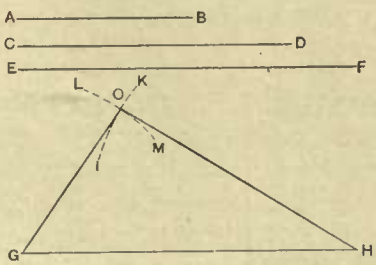


Fig. 165.—To Construct a Triangle, the Length of the Three Sides being Given.

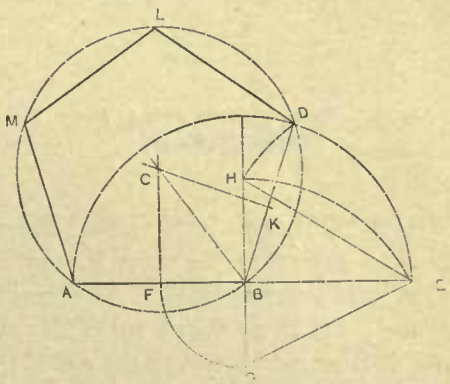


Fig. 166.—Upon a Given Side to draw a Regular Pentagon.

the remaining number of sides and draw connecting lines, which will complete the figure.

34. To Inscribe a Regular Polygon of Eleven Sides (Undecagon) within a Given Circle by the General Rule.—Through the given circle, E D F G in Fig. 163, draw any diameter, as E F, which divide into the same number of equal parts as the figure is to have sides, as shown by the small figures. At right angles to the diameter just drawn draw the radius D K, which divide into four equal parts. Prolong the radius D K

35. Upon a Given Side to Construct an Equilateral Triangle.—In Fig. 164, let A B represent the length of the given side. Draw any line, as C D, making it equal to A B. Take the length A B in the dividers, and placing one foot upon the point C, describe the arc E F. Then from D as center, with the same radius, describe the arc G H, intersecting the first arc in the point K. Draw K C and K D. Then C D K will be the required triangle.

36. To Construct a Triangle, the Length of the Three

Sides being Given.—In Fig. 165, let A B, C D and E F be the given sides from which it is required to construct a triangle. Draw any straight line, G H, making it in length equal to one of the sides, E F. Take the length of one of the other sides, as A B, in the compasses, and from one end of the line just drawn, as G, for center describe an arc, as indicated by L M. Then set the compasses to the length of third side, C D, and from the opposite end of the line first drawn, H, describe a second arc, as I K, intersecting the first in the point O. Connect O G and O H. Then O G H will be the required triangle.

37. Upon a Given Side to Draw a Regular Pentagon.—In Fig. 166, let A B represent the given side upon which a regular pentagon is to be constructed. With B as center and B A as radius, draw the semicircle A D E. Produce A B to E. Bisect the given side A B, as shown at the point F, and erect a perpendicular, as shown by F C. Also erect a perpendicular at the point B, as shown by G H. With B as center, and F B as radius, strike the arc F G, cutting the perpendicular H G in the point G. Draw G E. With G as center, and G E as radius, strike the arc E H, cutting the perpendicular in the point H. With E as center, and E H as radius, strike the arc H D, cutting the semicircle A D E in the point D. Draw D B, which will be the second side of the pentagon. Bisect D B, as shown, at the point K, and erect a perpendicular, which produce until it intersects the perpendicular F C, erected upon the center of the given side in point F. Then C is the center of the circle which circumscribes the required pentagon. From C as center, and with C B as radius, strike the circle, as shown. Set the dividers to the distance A B and step off the circumference of the circle, obtaining the points M and L. Draw A M, M L and L D, which will complete the figure.

38. Upon a Given Side to Draw a Regular Hexagon.—In Fig. 167, let A B be the given side upon which a regular hexagon is to be erected. From A as center, and with A B as radius, describe the arc B C. From B as center, and with the same radius, describe the arc A C, intersecting the first arc in the point C. C will then be the center of the circle which will circumscribe the required hexagon. With C as center, and C B as radius, strike the circle, as shown. Set the dividers to the space A B and step off the circumference, as shown, obtaining the points E, G, F and D. Draw the chords A E, E G, G F, F D and D B, thus completing the required figure.

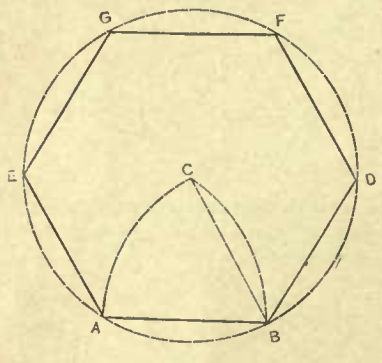


Fig. 167.—Upon a Given Side to Draw a Regular Hexagon.

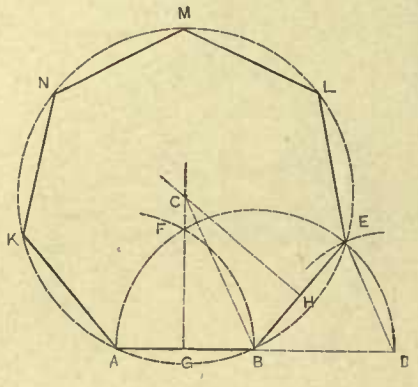


Fig. 168.—Upon a Given Side to Draw a Regular Heptagon.

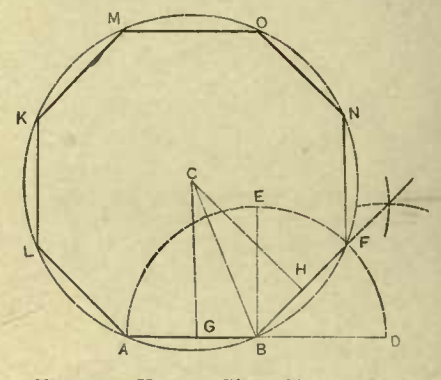


Fig. 169.—Upon a Given Side to Draw a Regular Octagon.

39. Upon a Given Side to Draw a Regular Heptagon.—In Fig. 168, A B represents the given side upon which a regular heptagon is to be drawn. From B as center, and with B A as radius, strike the semicircle A E D. Produce A B to D. From A as center, and with A B as radius, strike the arc B F, cutting the semicircle in the point F. Through F draw F G perpendicular to A B, which extend in the direction of C. From D as center, and with radius G F, cut the semicircle in the point E. Draw the line E B, which is another side of the required heptagon. Bisect E B, and upon its middle point, H, erect a perpendicular, which produce until it meets the perpendicular erected upon the center of the given side A B, in the point C. Then C is the center of the circle which will circumscribe the required heptagon. From C as center, and with C B as radius, strike the circle. Set the dividers to the distance A B and step off the circumference, as

shown, obtaining the points K, N, M and L. Draw the connecting arcs A K, K N, N M, M L and L E, thus completing the figure.

40. Upon a Given Side to Draw a Regular Octagon.—In Fig. 169, let A B represent the given side upon which a regular octagon is to be constructed. Produce A B indefinitely in the direction of D. From B as center, and with A B as radius, describe the semicircle A E D. At the point B erect a perpendicular to A B, as shown, cutting the circumference of the semicircle in the point E. Bisect the arc E D, obtaining the point F. Draw F B, which is another side of the required octagon. Bisect the two sides now obtained and erect perpendiculars to their middle points, G and H, which produce until they intersect at the point C. C then is the center of the circle that will circumscribe which produce until they intersect at the point C. Then C is the center of the circle which will circumscribe the required nonagon. From C as center, and with C B as radius, strike the circle B O P A. Set the dividers to the space A B and step off the circle, as shown, obtaining the points N, P, M, R, O and L. Draw the connecting chords, A N, N P, P M, M R, R O, O L and L E, thus completing the figure.

42. Upon a Given Side to Draw a Regular Decagon.—In Fig. 171, A B is the given side upon which a regular decagon is to be drawn. Produce A B indefinitely in the direction of D. From B as center, and with B A as radius, strike the semicircle A H D. Bisect the given side A B, obtaining the point F. Through the point B draw the line H B G, perpendicular to A B. From B as center, and with B F as

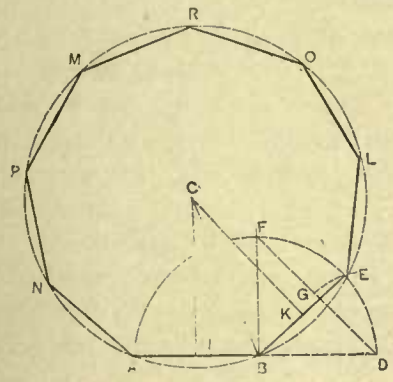


Fig. 170.—Upon a Given Side to Draw a Regular Nonagon.

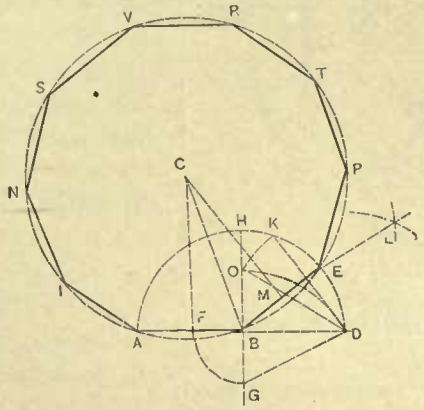


Fig. 171.—Upon a Given Side to Draw a Regular Decagon.

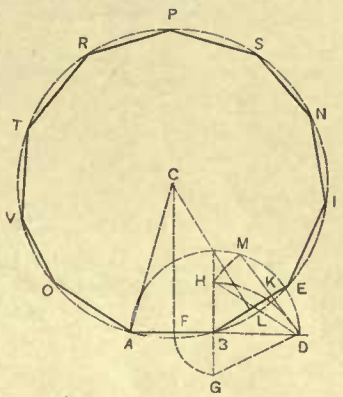


Fig. 172.—Upon a Given Side to Draw a Regular Undecagon.

the octagon. From C as center, and with C B as radius, strike the circle, as shown. Set the dividers to the space A B and step off the circumference, obtaining the points L, K, M, O and N. Draw the connecting arcs A L, L K, K M, M O, O N and N F, thus completing the required figure.

41. Upon a Given Side to Draw a Regular Nonagon.—In Fig. 170, A B is any given side upon which it is required to draw a regular nonagon. Produce A B indefinitely in the direction of D. From B as center, and with B A as radius, strike the semicircle A F D. At the point B erect a perpendicular to A B, cutting the semicircle in the point F. Draw the chord F D, which bisect, obtaining the point G. From D as center, and with D G as radius, cut the semicircle in the point E. Draw E B, which will be another side of the required figure. From the middle points of the two sides now obtained, as H and K, erect perpendiculars, radius, strike the arc F G, cutting the perpendicular H G in the point G. From G as center, and with G D as radius, strike the arc D O, cutting the perpendicular H G in the point O. From D as center, and with D O as radius, strike the arc O K, cutting the semicircle in the point K. Draw the line K D, which bisect with the line B L, cutting the semicircle in the point E. Then E B will be another side of the decagon. Upon the middle points, F and M, of the two sides now obtained erect perpendiculars, which produce until they intersect at the point C. Then C is the center of the circle which will circumscribe the required decagon. From C as center, and with C B as radius, strike the circle, as shown. Set the dividers to the space A B and step off the circle, obtaining the several points, I, N, S, V, R, T and P. Draw the connecting lines, A I, I N, N S, S V, V R, R T, T P and P E, thus completing the figure.

43. Upon a Given Side to Draw a Regular Undecagon.—In Fig. 172, A B represents the given side upon which a regular undecagon is to be drawn. Produce A B indefinitely in the direction of D. From B as center, and with B A as radius, draw the semicircle A M D. Through the point B, perpendicular to A B, draw the line H D indefinitely. From B as center, and with B F as radius, strike the arc F G, cutting the perpendicular H G in the point G. From G as center, and G D as radius, strike the arc D H, cutting the perpendicular H G in the point H. With D as center, and D H as radius, strike the arc H M, cutting the semicircle in the point M. Draw M D, which bisect, obtaining the point K, through which, from B, draw the line B K, and produce it until it cuts the semicircle in the point E. Then B E will be another side of the required figure. Bisect the two sides now obtained and erect perpendicular lines, producing them until they intersect, as shown by F C and L C. Then C, the point of intersection, is the center of the circle which circumscribes the undecagon. From C as center, and with C A as radius, strike the circle, as shown. Set the dividers to the space A B and step off the circumference, obtaining the points O, V, T, R, P, S, N and I. Draw the chords A O, O V, V T, T R, R P, P S, S N, N I and I E, thus completing the figure.

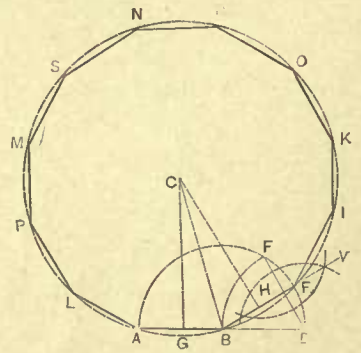


Fig. 173.—Upon a Given Side to Draw a Regular Dodecagon.

44. Upon a Given Side to Draw a Regular Dodecagon.—In Fig. 173, let A B represent the given side upon which a regular dodecagon is to be drawn. Produce A B indefinitely in the direction of D. From B as center, and with B A as radius, describe the semicircle A F D. From D as center, and with D B as radius, describe the arc B F, cutting the semicircle in the point F. Draw F D, which bisect by the line V B, cutting the semicircle in the point E. Then E B is another side of the dodecagon. From the middle points of the two sides now obtained, as G and H, erect perpendiculars, as shown, cutting each other at the point C. This point of intersection, C, then is the center of the circle which will circumscribe the required dodecagon. From C as center, and with C B as radius, strike the circle, as shown. Set the dividers to the distance A B and space off the circumference, thus obtaining the points L, P, M, S, N, R, O, K and I. Draw the connecting lines L P, P M, M S, S N, N R, R O, O K, K I and I E, thus completing the figure.

45. General Rule by which to Draw any Regular Polygon, the Length of a Side Being Given.—With a radius equal to the given side describe a semicircle, the circumference of which divide into as many equal parts as the figure is to have sides. From the center by which the semicircle was struck draw a line to the second division in the circumference. This line will be one side of the required figure, and one-half of the diameter of the semicircle will be another, and the two will be in proper relationship to each other. Therefore, bisect each, and through their centers erect perpendiculars, which produce until they intersect. The point of intersection will be the center of the circle which will circumscribe the polygon. Draw the circle, and setting the dividers to the length of one of the sides already found, step off the circumference, thus obtaining points by which to draw the remaining sides of the figure.

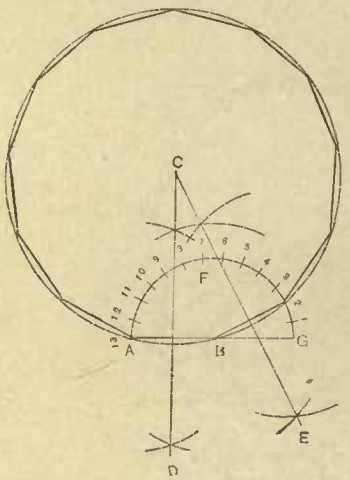


Fig. 174.—Upon a Given Side to Construct a Regular Polygon of Thirteen Sides by the General Rule.

46. To Construct a Regular Polygon of Thirteen Sides by the General Rule, the Length of a Side being Given.—In Fig. 174, let A B be the given side. With B as center, and with B A as radius, describe the semicircle A F G. Divide the circumference of the semicircle

into thirteen equal parts, as shown by the small figures, 1, 2, 3, 4, etc. From B draw a line to the second division in the circumference, as shown by B 2. Then A B and B 2 are two of the sides of the required figure, and are in correct relationship to each other. Bisect A B and B 2, as shown, and draw D C and E C through their central points, prolonging them until they intersect at the point C. Then C is the center of the circle which will circumscribe the required polygon. Strike the circle, as shown. Set the dividers to the space A B, and step off corresponding spaces in the circumference of the circle, as shown, and connect the several points so obtained by lines, thus completing the figure.

47. Within a Given Square to Draw a Regular Octagon.—In Fig. 175, let A D B E be any given square within which it is required to draw an octagon. Draw the diagonals D E and A B, intersecting at the point C. From A, D, B and E as centers, and with radius equal to one-half of one of the diagonals, as A C, strike the several arcs H N, G K, I M and L O, cutting the sides of the square, as shown. Connect the points thus obtained in the sides of the square by drawing the lines G O, H I, K L and M N, thus completing the figure.

For general use a very convenient scale may be constructed, as shown in Fig. 176, from which half the length of one side of a polygon of any number of sides and of any diameter in inches and fractions of

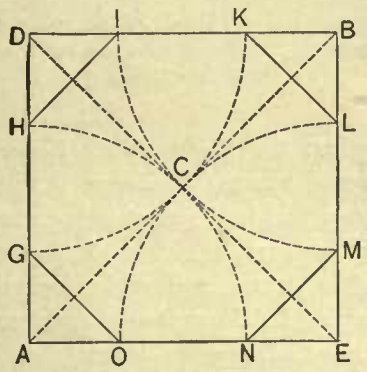


Fig. 175.—Within a Given Square to Draw a Regular Octagon.

inches may readily be obtained. Draw the vertical line O B and divide it into inches and parts of an inch. From these points of division draw horizontal lines; from the point O draw the following lines and at the following angles from the horizontal line O P:

A line at 75° for polygons having 12 sides.
" 72° " " 10 "
" 67½° " " 8 "
A line at 60° for polygons having 6 sides.
" 54° " " 5 "
" 45° " " 4 "

The figures on O B will designate the radius of the inscribed circle measured from O. The distance from O B on any horizontal line to the oblique line de-

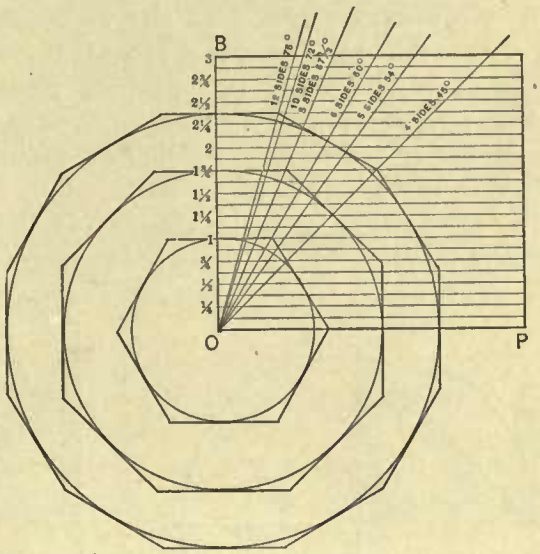


Fig. 176.—Scale for Constructing Polygons of any Number of Sides, the Diameter of the Inscribed Circle Being Given in Inches.—Half Full Size.

noting the required polygon will be half the length of a side of the polygon of the diameter indicated by the figure at the end of the horizontal line assumed. The distance from O measured upon the oblique line to the assumed horizontal line will be the radius of the circumscribed circle.

In the engraving three polygons are drawn showing the application of the scale.

II.—BY THE USE OF THE T-SQUARE AND TRIANGLES OR SET-SQUARES.

In the chapter upon terms and definitions under the word *degree* (def. 68) and in some of those immediately following the dimensions of the circle are described and their use explained; and in the chapter upon Drawing Tools and Materials (on page 21) the triangles or set-squares in common use are described and illustrated. As all regular polygons depend, for their construction, upon the equal division of the circle, some explanation of the application of the foregoing will serve to fix a few facts in the mind of the student and thus prepare him for the use of the set-square.

A well-known and easily demonstrated geometrical principle is that the sum of the three interior angles of a triangle is equal to two right angles, or in other words, as a right angle is one of 90 degrees, if the three angles of any triangle be added together their sum will equal 180 degrees. Hence, if one of the angles of a set-square be fixed at 90 degrees (which is done for convenience in drawing perpendicular lines) the sum of the two remaining angles must also be 90 degrees, and, if then the two other angles be made equal, each will be 45 degrees, which is the half of 90 degrees. If, however, one of the other angles is fixed at 30 (one-third of 90 degrees), the remaining angle must be 60 degrees, as $30 + 60 = 90$.

By means, then, of the 45-degree and the 30 × 60-degree triangles, the draftsman has at his command the means of drawing lines at angles of 90, 60, 45 and 30 degrees, and by combination 75 degrees (45 + 30) and 15 degrees (90 − 75). With the 45-degree angle he can bisect a right angle, and with the 30 and 60-degree angles he can trisect it.

The pattern draftsman sometimes finds it convenient to have a set-square in which the sharpest angle is one of 22½ degrees (one-half of 45) for use in drawing the octagon in a certain position which will be referred to later.

In Figs. 177, 178, 179 and 180 are illustrated the application of the foregoing, in which the circle is divided, by the use of the triangles above described, into four, eight and twelve equal parts. In Fig. 177 the horizontal division A B of the circle is drawn by means of the T-square placed against the side of the drawing board, after which one of the shorter sides of the 45-degree triangle, as A E, is placed against the blade of the T-square, and the vertical division of the circle is drawn along the other short side C E.

In Fig. 178 the vertical and horizontal divisions of the circle, A B and C D, are drawn as before, after which one of the shorter sides of the 45-degree triangle is placed against the T-square, and the long or oblique side E F is brought to the center of the circle and another division G I is drawn. By reversing the position of the triangle the last division H K is drawn, thus dividing the circle into eight equal parts.

In Fig. 179, after drawing the divisions A B and C D as before, the 30 × 60-degree triangle is placed in the position shown at A E F, and the division E N is drawn along its hypothenuse or oblique side. By reversing the position of the triangle, still keeping the side A F against the blade of the T-square, the division J K may be drawn. Changing the position of the triangle now so that its shortest side comes against the blade of the T-square, as shown dotted at G H F, the division G M is drawn, and again reversing its position, still keeping its shortest side against the T-square, the last division I L may be drawn, thus dividing the circle into twelve equal parts.

In Fig. 180 the circle is divided into eight equal parts, but differing from that shown above in this respect that, while in Fig. 178 two of the divisions lie parallel with the sides of the drawing board, in the latter case none of the divisions are parallel with the sides of the board or can be drawn with the T-square; but if this method is used in drawing an octagon, as shown dotted in Fig. 180, four of the sides of the octagon can be drawn with the T-square and the other

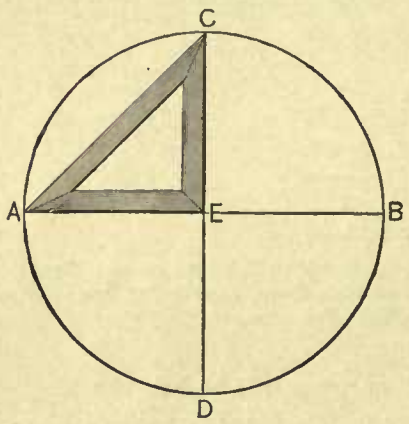


Fig. 177.—Circle Divided into Four Equal Parts by the Use of a Triangle or Set-Square.

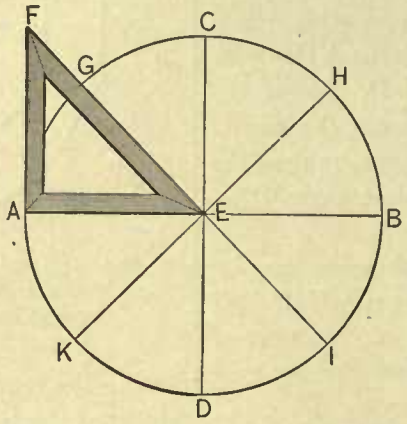


Fig. 178.—Circle Divided into Eight Equal Parts by the Use of a 45-degree Triangle.

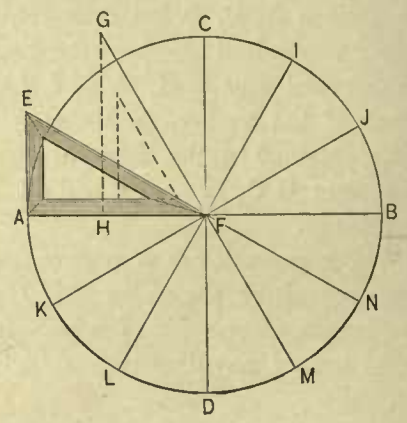


Fig. 179.—Circle Divided into Twelve Equal Parts by the Use of a 30 × 60-degree Triangle.

four with the 45-degree triangle. The position of the $22\frac{1}{2} \times 67\frac{1}{2}$-degree triangle in drawing the divisions of the circle is shown at A B C and D E C, while the position of the 45-degree triangle in drawing the oblique sides of an octagon figure is shown at F. It will thus be seen that the $22\frac{1}{2} \times 67\frac{1}{2}$-degree triangle is available in drawing accurately the miter line for all octagon miters.

As a triangle in whatever form it may be constructed is intended to be used by sliding it against the blade of the T-square, all the angles above mentioned are calculated with reference to the lines drawn by the T-square. In practical use it will be found inconvenient in drawing such lines to actually bring the point of a set-square to the center of a circle. A better method, and one which makes use of the same principles, is shown in Fig. 181. The blade of the

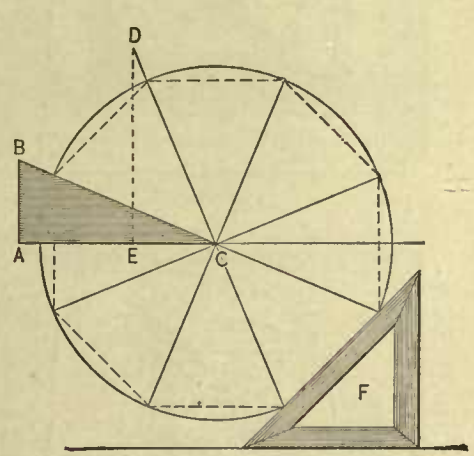


Fig. 180.—Circle Divided into Eight Equal Parts by the Use of a 22½ × 67½-degree Triangle.

T-square is placed tangent to or near the circle, as shown by A B. One side of a 45-degree triangle is placed against it, as shown, its side C F being brought against the center. The line C F is then drawn. By reversing the triangle, as shown by the dotted lines, the line E D is drawn at right angles to C F, thus dividing the circle into quarters.

A similar use of the 30 × 60-degree triangle is shown in Fig. 182, by which a circle is divided into six equal parts. Bring the blade of the T-square tangent to or near the circle, as shown by A B. Then place the set-square as shown by G B M, bringing the side G B against the center of the circle, drawing the line D L. Then place it as shown by the dotted lines, bringing the side A H against the center, scribing the line F E. Then, by reversing the set-square, placing the side G M against the straight-edge, erect the perpendicular C I, completing the division. The following are a few of the problems to which these principles may be advantageously applied.

48. To Inscribe an Equilateral Triangle within a Given Circle.—In Fig. 183, let D be the center of the given circle. Set the side E F of a 30-degree set-square against the T-square, as shown, and move it along

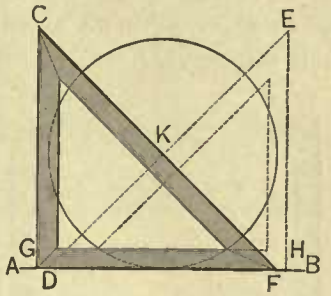


Fig. 181.—Proper Method of Using a 45-degree Triangle.

until the side E G touches D. Mark the point B upon the circumference of the circle. Reverse the set-square so that the point E will come to the right of the side F G and move it along in the reversed position until the side E G again meets the point D, and mark the point C. Now move the T-square upward until it touches the point D, and mark the point A. Then A B and C are points which divide the circle into three equal parts. The triangle may be easily completed from this stage by drawing lines connecting A B, B C and C A, with any straight-edge or rule, but greater accuracy is obtained by the further use of the set-square, as follows: Place the side F G of the set-square against the T-square, as shown in Fig. 184,

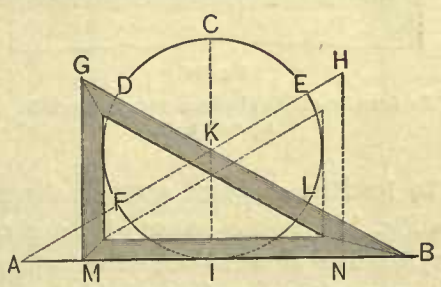


Fig. 182.—Method of Using a 30 × 60-degree Triangle in Dividing the Circle.

and move it along until the side E G touches the points A and C, as shown. Draw A C, which will be one side of the required triangle. Set the side E F of the set-square against the T-square, and move it along until the side F G coincides with the points C and B. Then draw C B, which will be the second side of the triangle.

Place the side F G of the set-square against the T-square, with the side E F to the right, and move it along until the side E G coincides with the points A and B. Then draw A B, thus completing the figure. The same results may be accomplished with less work by first establishing the point A by bringing the T-square against the center, and then using the set-square, as shown in Fig. 184. The different methods are here given in order to more clearly illustrate the use of the tools employed.

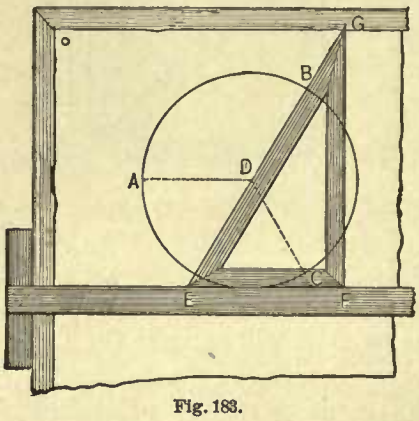


Fig. 183.

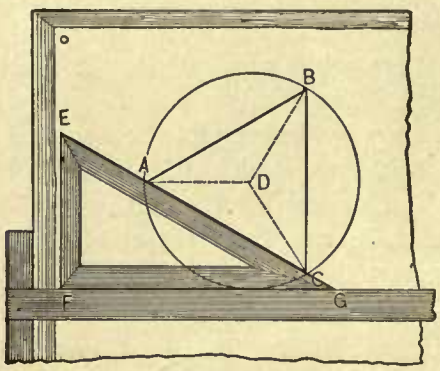


Fig. 184.

To Inscribe an Equilateral Triangle within a Given Circle.

49. To Inscribe a Square within a Given Circle— Let D, in Fig. 185, be the center of the given circle. Place the side E F of a 45-degree set-square against the T-square, as shown, and move it along until the side E G meets the point D. Mark the points A and B. Reverse the set-square, and in a similar manner mark the points C and H. The points A, H, B and C are corners of the required square. Move the T-square upward until it coincides with the points A and H and draw A H, as shown in Fig. 186. In like manner draw C B. With the side E F of the set-square against the T-square, move it along until the side G F coincides with the points B and H, and draw B H. In a similar manner draw C A, thus completing the figure.

50. To Inscribe a Hexagon within a Given Circle.— In Fig. 187, let O be the center of the given circle. Place the side E F of a 30-degree set-square against the T-square, as shown. Move the set-square along until the side E G meets the point O. Mark the points A and B. Reverse the set-square, and in like manner mark the points C and D. With the side F G of the set-square against the T-square, move it along until

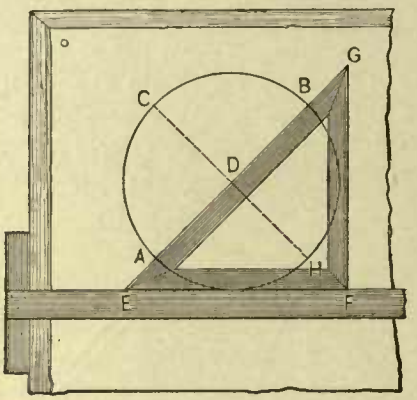


Fig. 185.

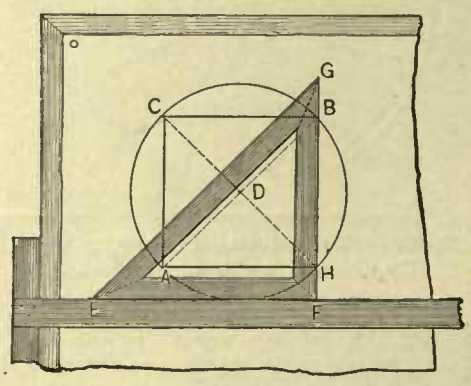


Fig. 186.

To Inscribe a Square within a Given Circle.

the side E F meets the point O, and mark I and H. Then A, H, D, B, I and C represent the angles of the proposed hexagon. From this stage the figure may be readily finished by drawing the sides by means of these points, using a simple straight-edge; but greater accuracy is attained in completing the figure by the further use of the set-square, as shown in Fig. 188. With the side E F of the set-square against the T-square, as shown, draw the line H D, and by moving the T-square upward draw the side C I. Reversing the set-square so that the point F is to the left of the point E, draw the side A H, and also, by shifting the

T-square, the side I B. With the edge E F of the set-square against the T-square, move it up until the side G F coincides with the points B and D, and draw the side B D. In like manner draw A C, thus completing the figure. In this figure, as with the triangle, the same results may be reached by establishing the points H and I, by means of a diameter drawn at right angles to the T-square, as shown in the engravings, and, using it as a base, employing the set-square, as shown in Fig. 188. The first method shown is, however, to be preferred in many instances, on account of its great accuracy.

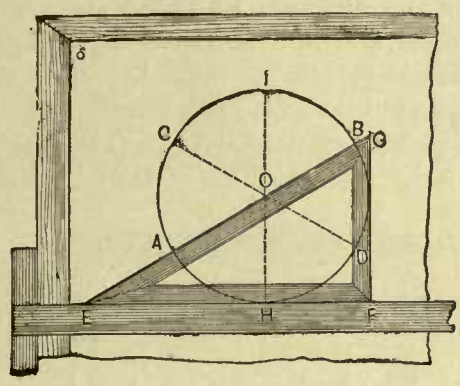


Fig. 187.

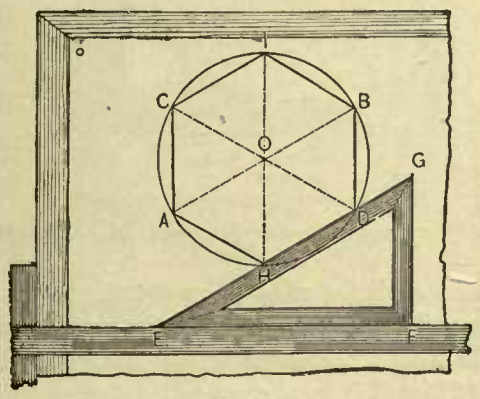


Fig. 188.

To Inscribe a Regular Hexagon within a Given Circle.

51. To Inscribe an Octagon within a Given Circle.—In Fig. 189, let K be the center of the given circle. Place a 45-degree set-square as shown in the engraving, bringing its long side in contact with the center, and mark the points E and A. Keeping it in the same position, move it along until its vertical side is in contact with K and mark the points D and H. Reverse the set-square from the position shown in the engraving, and mark the points C and G. Move the T-square upward until it touches the point K, and mark the points B and F. Then A, H, G, F, E, D, C and B are corners of the octagon. The figure may now be readily completed by drawing the sides, by means of these points, using any rule or straight-edge for the purpose,

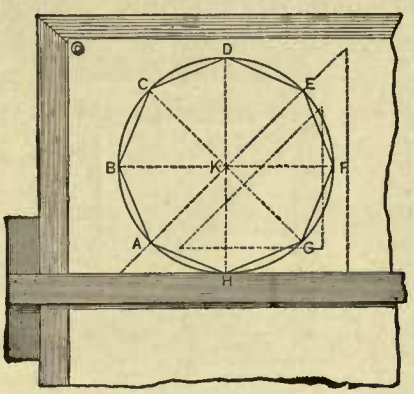


Fig. 189.—To Inscribe a Regular Octagon within a Given Circle.

all as shown by A H, H G, G F, F E, E D, D C, C B and B A, or by means of a $22\frac{1}{2} \times 67\frac{1}{2}$-degree set-square.

52. To Draw an Equilateral Triangle upon a Given Side.—In Fig. 190, let A B be the given side. First bring the line A B at right angles to the blade of the T-square. Then set the edge C B of a 30-degree set-square against the T-square, and move it along until the edge B D meets the point B, and draw the line B F. Reverse the set-square, still keeping the side C B against the T-square, and move it along until the side B D meets the point A, and draw the line A F, thus completing the figure.

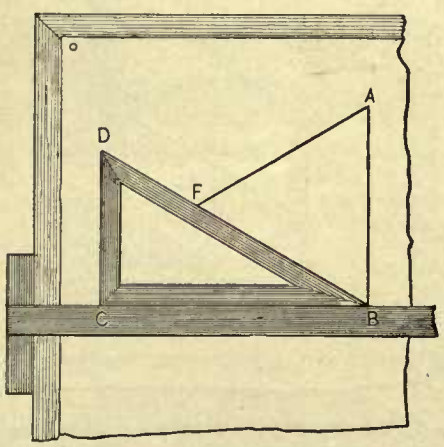


Fig. 190.—To Draw an Equilateral Triangle upon a Given Side.

53. To Draw a Square upon a Given Side.—In Fig. 191, let A B be the given side drawn at right angles

to the blade of the T-square. Set the edge E F of a 45-degree set-square against the T-square, as shown, and move it along until the side E G meets the point B, and draw B I indefinitely. Reverse the set-square, and, bringing the side E G against the point A, draw A

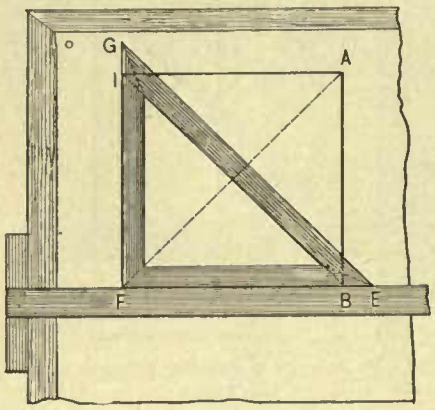


Fig. 191.—To Draw a Square upon a Given Side.

F indefinitely. Bring the T-square against the point B and draw B F, producing it until it meets the line A F in the point F. In like manner draw A I, meeting the line B I in the point I. Then, with the set-square placed as shown in the engraving, connect I and F, thus completing the required figure.

54. To Draw a Regular Hexagon upon a Given Side.—In Fig. 192, let A B be the given side in a vertical position. Set the edge G H of a 30-degree set-square against the T-square, as shown, and move it along

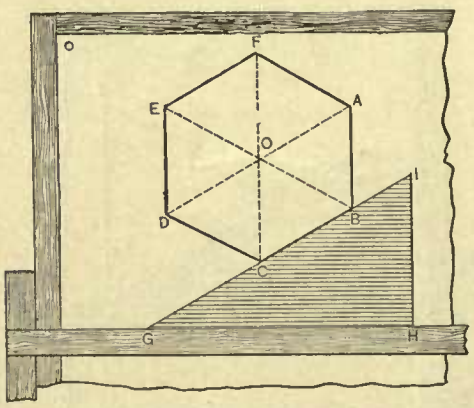


Fig. 192.—To Draw a Regular Hexagon upon a Given Side.

until the edge I G coincides with the point A, and draw the line A D indefinitely. Reverse the set-square, still keeping the edge G H against the T-square, and move it along until the side I G coincides with the point B, and draw B E indefinitely. These lines will intersect in the point O, which will be the center of the required figure. Still keeping the edge G H of the set-square against the T-square, move it along until the perpendicular edge I H meets the point O, and through O draw F C indefinitely. With the set-square in the position shown in the engraving slide it along until the edge I G meets the point B, and draw B C, producing it until it meets the line F C in the point C. Reverse the set-square, still keeping the edge G H against the T-square, and draw the line C D, producing it until it meets the line A D in the point D. Slide the set-square along until the side I H meets the point D, and draw the line D E, meeting the line B E in the point E. Move the set-square along until the edge I G meets the point A, and draw the line A F, meeting the line C F in the point F. Now bring the set-square to its first position and

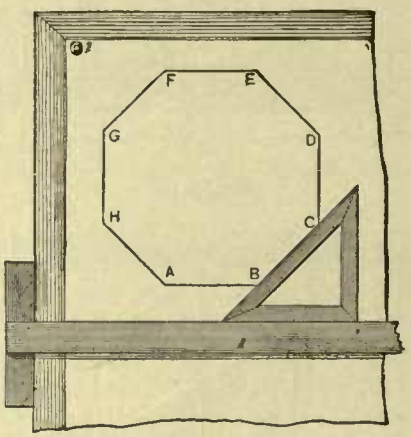


Fig. 193.—To Draw a Regular Octagon upon a Given Side.

slide it along until the edge I G meets the points F and E, and draw F E, thus completing the required figure.

55. To Draw a Regular Octagon upon a Given Side.—In Fig. 193, let C D be the given side, drawn perpendicular to the blade of the T-square. Place one of the short sides of a 45-degree set-square against the T-square, as shown in the engraving. Move the set-square along until its long side coincides with the point C. Draw the line C B, and make it in length equal to C D. With the T-square draw the line A B, also in length equal to C D. Reverse the set-square, and bring the edge against the point A. Draw A H in length the same as C D. Still keeping a short side of the set-square against the T-square, slide it along until the other short side meets the point H, and draw H G, also of the same length. Then, using the long side of the set-square, draw G F of corresponding length. By means of the T-square draw F E, and by reversing the set-square draw E D, both in length

equal to the original side, C D, joining it in the point D, thus completing the required octagon.

56. To Draw an Equilateral Triangle about a Given Circle.—In Fig. 194, let O be the center of the given circle. Place the edge E F of a 30-degree set-square against the T-square, as shown, and move it along until the edge F G meets the center O, and mark the point A upon the circumference of the circle. Reverse the set-square, still keeping the edge E F against the T-square, and in like manner mark the point B. Move

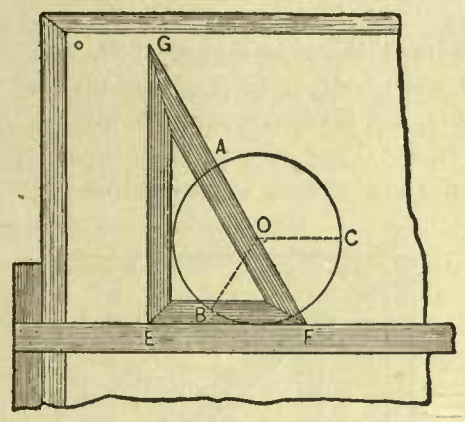


Fig. 194.

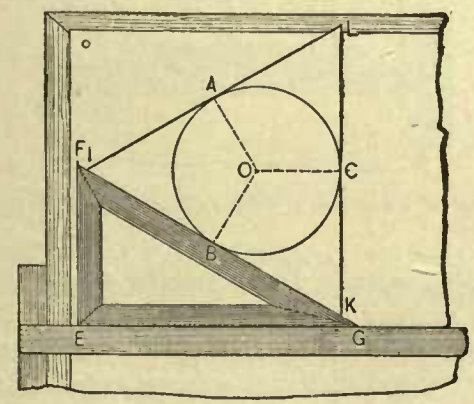


Fig. 195.

To Draw an Equilateral Triangle about a Given Circle.

the T-square upward until it meets the point O, and mark the point C. The required figure will be described by drawing lines tangent to the circle at the points A, B and C, which may be done in the manner following, as indicated in Fig. 195 Place the edge E G of the set-square against the T-square, and slide it along until the edge F G touches the circle in the point B. Draw I K indefinitely. Reverse the set-square, keeping the same edge against the T-square, and move it along until its edge F G touches the circle in the point A, and draw I L, intersecting I K in the point I, the other end being indefinite. Then, placing the edge F E of the set-square against the T-square, bring its edge E G against the circle in the point C, and draw L K, intersecting I D in the point L and I K in the point K, thus completing the figure. The first part of this operation is not really necessary. The sides of the set-square simply can be brought tangent to the circle, as in Fig. 195.

57. To Draw a Hexagon about a Given Circle.—In Fig. 196, let O be the center of the given circle. Place

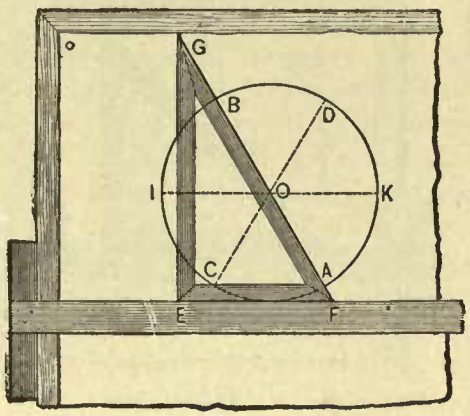


Fig. 196.

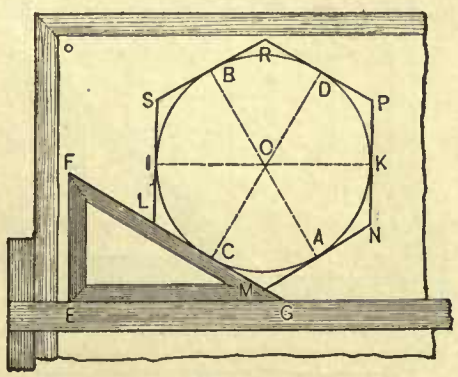


Fig. 197.

To Draw a Hexagon about a Given Circle.

the edge E F of a 30-degree set-square against the T-square, and slide it along until the edge F G meets the point O, and mark the points B and A. Reverse the set-square, still keeping the edge E F against the T-square, and in like manner mark the points C and D. Bring the edge of the T-square against O, and mark the points I and K. Then C, A, K, D, B and I are six points in the circumference of the circle, corresponding to the six sides of the required figure. The hexagon is completed by drawing a side tangent to the circle at each of these several points, which may be done by using

the set-square as follows, and as shown in Fig. 197. With the edge E G of the set-square against the T-square, bring the edge F G against the circle at the point C, as shown, and draw L M indefinitely. Reverse the set-square, and in like manner bring it against the circle at the point A, and draw M N, cutting L M in the point M, and extending indefinitely in the direction of N. Slide the set-square along until the edge E F meets the circle in the point K, and draw N P, intersecting M N in the point N, and extending in the

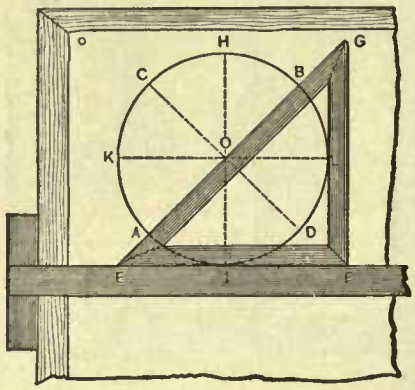


Fig. 198.

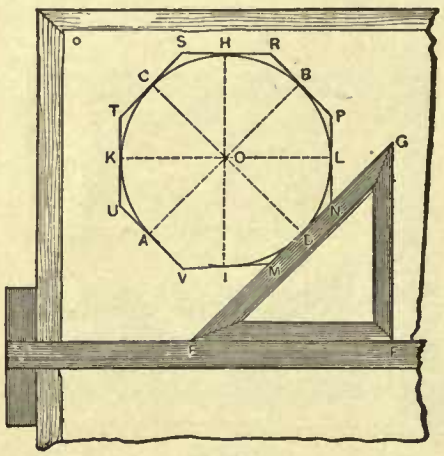


Fig. 199.

To Draw an Octagon about a Given Circle.

direction of P indefinitely. With the set-square in its first position slide it along until the edge F G meets the circle in the point D, and draw R P, cutting N P in the point P, but being indefinite in the direction of R. Reverse the set-square, and in like manner draw R S tangent to the circle in the point B, cutting P R in the point R, and extending in the direction of S indefinitely. Slide the set-square along until its edge E F meets the circle in the point I, and draw S L, cutting R S in the point S and L M in the point L, thus completing the required figure.

In this problem, as in the previous one, if care be taken the first part of the operation can be dispensed with by simply placing the triangle in proper position and drawing the sides of the figure tangent to the circle, as shown in Fig. 197.

58. To Draw an Octagon about a Given Circle.—In Fig. 198, let O be the center of the given circle. With the edge E F of a 45-degree set-square against the T-square, as shown, move it along until the side E G meets the point O, and mark the points A and B. Reverse the set-square, and in like manner mark the points C and D. Slide the set-square along until the vertical side G F meets the point O, and mark the points H and I. Move the T-square up until it meets the point O, and mark the points K and L. Then A, I, D, L, B, H, C and K are points in the circumference of the given circle corresponding to the sides of

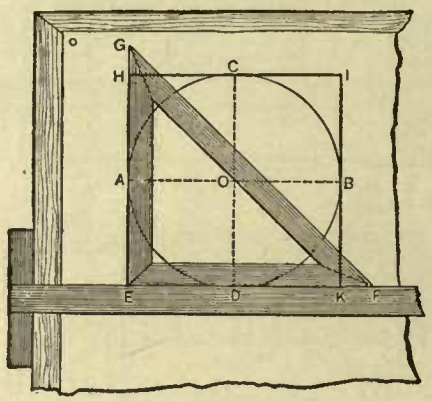


Fig. 200.—To Draw a Square about a Given Circle.

the required figure. The octagon is then to be completed by drawing lines tangent to the circle at these several points, as shown in Fig. 199, which may be done by the use of the set-square, as follows: With the edge E F of the set-square against the T-square, as shown, bring the edge E G against the circle in the point D, and draw M N indefinitely. Sliding the set-square along until the vertical edge F G meets the circle in the point L, draw N P, cutting M N in the point N, and extending in the opposite direction indefinitely. Reverse the set-square, and bringing the edge E G against the circle in the point B, draw P R, cutting N P in the point P, and extending indefinitely in the direction of R. Move the T-square upward until it meets the circle in the point H, and draw the line S R, meeting P R in the point R, and extending indefinitely in the opposite direction. Then, with the set-square placed as shown in the engraving, move it

until its edge E G meets the circle in the point C, and draw S T, meeting S R in the point S, and continuing indefinitely in the direction of T. With the set-square in the same position, move it along until its edge G F meets the circle in the point K, and draw T U, cutting S T in the point T, and extending in the opposite direction indefinitely. Reverse the set-square, and bringing its long side against the circle in the point A, draw U V, cutting T U in the point U, and continuing indefinitely in the opposite direction. Bring the T-square against the circle in the point I, and draw V M, connecting U V and M N in the points V and M respectively, thus completing the figure. The above rule will be found very convenient for use, although, as the student may discover, the first part of the operation is not absolutely necessary.

59. To Draw a Square about a Given Circle.—In Fig. 200, let O be the center of the given circle. Place

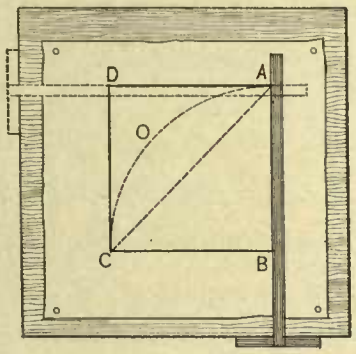


Fig. 201.—To Draw a Square upon a Given Side.

the blade of the T-square against the point O, and draw the line A O B. With one of the shorter sides E F, of a 45-degree set-square against the T-square, and with the other short side against the point O, draw the line D O C. Move the T-square upward until it strikes the point C, and draw the line H C I. Move it down until it strikes the point D, and draw the line E D K. With the side E F of the set-square against the T-square, as shown in the engraving, bring the side E G against the point A, and draw E A H. In like manner bring it against the point B, and draw K B I, thus completing the figure. It is to be observed that the several lines composing the sides of the square are tangent to the circle in the points A C B and D respectively. The only object served by drawing the diameters A B and C D is that of obtaining greater accuracy in locating the points of tangency.

60. To Draw a Square upon a Given Side.—Let A B of Fig. 201 be the given side placed parallel to one side of the drawing board. Place one of the shorter edges of a 45-degree set-square against the T-square, as placed for drawing the given side, and slide it along until the long edge touches the point A, and draw the diagonal line A C indefinitely. Place the T-square so that its head comes against the left side of the board, as shown by the dotted lines in the engraving, and, bringing the blade against the point A, draw A D indefinitely. Then bringing the blade against the point B, draw B C, stopping this line at the point of intersection with the line A C, as shown at C. Bring the T-square back to the original position and draw the line C D, thus completing the figure. In the case of a large drawing board, unless the figure is to be located very near one corner of it, or in the case of a drawing board of which the adjacent sides are not at right angles, it will be desirable to use the right angle of the set-square, instead of changing the T-square from one side to the other, as above described. The object of drawing the diagonal line A C is to determine the length of the side C B. This also may be done by the use of the compasses instead of the set-square, as follows: From B as center, with B A as radius, describe the arc A O C. Place the T-square as shown by the dotted lines, and, bringing it against the point B, draw B C, producing it until it intercepts the arc A O C in the point C. The remaining steps are then to be taken in the manner above described.

III.—BY MEANS OF THE PROTRACTOR.

The protractor. which has been already described and illustrated (see Fig. 116, Chapter II), is an instrument for measuring angles. The usual form of this instrument is a semicircle with a graduated edge, the divisions being more or less numerous, according to its size. In instruments of ordinary size the divisions are single degrees, numbered by 5s or by 10s, while in larger sizes the divisions are made to fractions of degrees.

Since the protractor by its construction affords the means of measuring or of setting off any angle whatsoever, it is especially useful in circumscribing or inscribing polygons, or of erecting them upon a given side. As its use is of infrequent occurrence among pattern draftsmen, only a few problems in inscribing will be given, which will be sufficient to enable the reader to apply it in other cases that may arise.

61. To Inscribe an Equilateral Triangle within a Given Circle.—In Fig. 202, let O be the center of the given circle. Through O draw a diameter, as shown by

C O D. Place the protractor so that its center point shall coincide with O, and turn it until the point marking 60 degrees falls upon the line C O D. Then mark points in the circumference of the circle corresponding to 0 (zero) and 120 degrees of the protractor, as shown by B and E respectively. Draw the lines C E, E B and B C, thus completing the required figure. The reasons for these several steps are quite evident. The circle consists of 360 degrees. Then each side of an equilateral triangle must represent one-third of 360 degrees, or 120 degrees. Assume the point C for one of the angles, and draw the line C O D. Then, by the nature of the figure to be drawn, D must fall opposite the center of one side. Therefore, since 60 is the half of 120 (the length of one side in degrees), place 60 opposite the point D, and mark 0 and 120 for the other angles, then complete the figure by drawing the lines

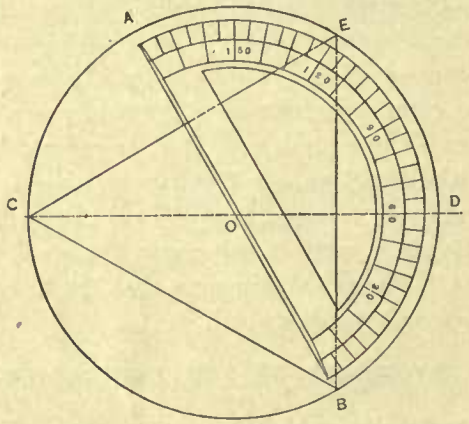


Fig. 202.—To Inscribe an Equilateral Triangle within a Given Circle.

as shown. Since in many cases the protractor is much smaller than the circle in which the figure is to be constructed, it becomes necessary to mark the points at the edge of the instrument, and carry them to the circumference by drawing lines from the center of the circle through the points, producing them until the circle is reached.

62. To Inscribe a Square within a Given Circle.—In Fig. 203, let O be the center of the given circle. Through O draw a diameter, as shown by C O D. Place the protractor so that its center point coincides with O, and turn it until the point marking 45 degrees falls upon the line C O D. Mark points in the circumference of the circle corresponding to 0, 90 and 180 degrees of the protractor, as shown by F, G and E respectively. From G, through the center O, draw G O H, cutting the circumference of the circle in the point H. Then E, G, F and H are the angles of the required figure, which is to be completed by drawing the sides E G, G F, F H and H E. Since the circle is composed of 360 degrees, one side of an inscribed square must represent one-fourth part of 360 degrees, or 90 degrees. The half of 90 degrees is 45 degrees. Hence, in setting the protractor, the point representing 45 degrees was placed opposite the point in which it is desired the center of one of the sides shall fall, or, in other words, upon the line C O D. Then, having marked points 90 degrees removed from each other, or, as explained above, opposite the points 0, 90 and 180 of the protractor, as shown by F, G and E, the fourth point was obtained by the diagonal line. It is evident that H must fall opposite G, upon a line drawn through the center. Or the protractor might have been moved around, and a space of 90 degrees measured from either

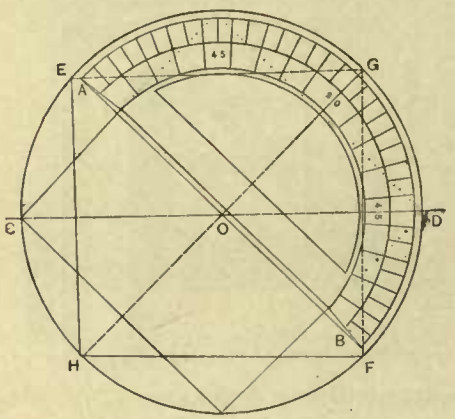


Fig. 203.—To Inscribe a Square within a Given Circle.

F or E, which, as will be clearly seen, would have given the same point, H.

63. To Inscribe an Octagon within a Given Circle.—Through the center O of the given circle, Fig. 204, draw a diameter, A O B, upon which the center of one side is required to fall. Place the protractor so that its center point shall coincide with the center O, and turn it so that the point representing 22½ degrees shall fall on the line A O B. Then mark points in the circumference of the circle corresponding to 0, 45, 90, 135 and 180 degrees of the protractor, as shown by E, G, H, I and F. Reverse the protractor, and in like manner mark the points M, L and K; or these points may be obtained by drawing lines from I, H and G respectively through the center O, cutting the circumference in M, L and K. The figure is to be completed by drawing the sides F I, I H, H G, G E,

E M, M L, L K and K F. Since the circle consists of 360 degrees, one side of an octagon must represent 45 degrees, or one-eighth of 360. The half of 45 is 22½. Hence, the point of the protractor representing 22½ degrees was placed upon the line A O B, which represents the center of one side of the required figure. Having thus established the position of one side, the other sides of the figure are located by marking points in the circumference of the circle opposite points in the protractor at regular intervals of 45 degrees.

64. To Inscribe a Dodecagon within a Given Circle.—In Fig. 205, let O be the center of the given circle.

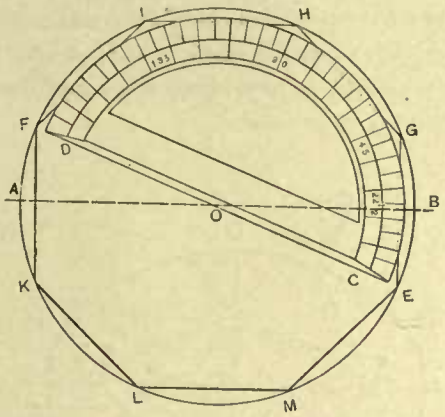


Fig. 204.—To Inscribe an Octagon within a Given Circle.

Through O draw the diameter A O B, at right angles to which one of the sides of the polygon is required to be. Set the protractor so that the center point of it coincides with the center O, and revolve it until the point marking 15 degrees falls upon the line A O B. With the protractor in this position, mark points in the circumference of the circle opposite the points in the protractor representing 0, 30, 60, 90, 120, 150 and 180 degrees, as shown by E, F, G, H, I, K and L. Then these points will represent angles of the required polygon. The remaining angles may be obtained by placing the protractor in like position in the opposite half of the semicircle, or they may be determined by drawing lines from the points F, G, H, I and K through the center O, producing them until they cut the circumference in the points M, N, P, R and S, which are the remaining angles. The figure is now to be completed by drawing the sides, as shown. In a dodecagon, or twelve-sided figure, each side must occupy a space represented by one-twelfth of 360 degrees, or 30 degrees of the protractor. As the side F E was required to be located in equal parts upon opposite sides of A O B, the middle of one division of the protractor representing a side (that is, 15 degrees, or one-half of 30 degrees) was placed upon the line A O B. Having thus established the position of one side, the others are measured off in manner above described.

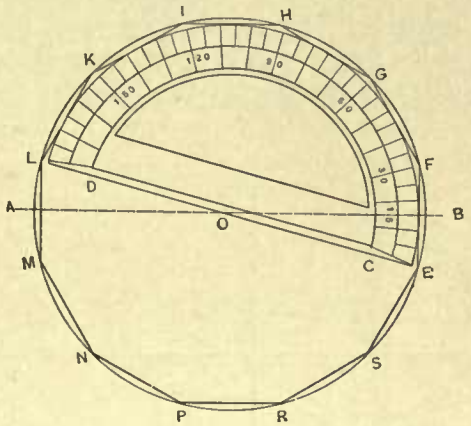


Fig. 205.—To Inscribe a Dodecagon within a Given Circle.

In making use of the protractor to erect a regular polygon upon a given side, the exterior angle, or angle formed by an adjacent side with the given side extended, as E B D in Figs. 168, 170 and 171, is found by dividing 360 degrees by the number of sides in the required polygon; while the interior angle, or angle between any two adjacent sides on the inside of the polygon, as E B A in the same diagrams, is the supplement of that angle, or, in other words, is found by subtracting the exterior angle from 180 degrees. Thus to find the exterior angle by means of which to construct a regular decagon, divide 360 degrees by 10, which gives 36 degrees; while the interior angle is equal to 180 degrees less 36 degrees, which is 144 degrees.

THE ELLIPSE.

For a definition of the ellipse the reader is referred to Chapter I, definitions 78 and 113. It may also be described as a curve drawn with a constantly increasing or diminishing radius, or as similar to a circle, but having one diameter longer than another, the diameters referred to being at right angles to each other.

If, upon one of two lines intersecting each other at right angles, half of the long diameter be set off each way from their intersection (A A, Fig. 206) and upon the other line half of the short diameter be set off each way from the intersection (B B, Fig. 206), four principal points in the circumference of the ellipse will thus

be established; and through these four points only one perfect ellipse can be drawn, one-quarter of which is shown by the solid line from A to B in the illustration. It is true that other curves having the appearance of an ellipse can be drawn through these points, as shown by the dotted lines, but, as stated above, there is only one curved line existing between those points which can be correctly termed an ellipse.

There are several methods of producing a correct ellipse, as by a string and pencil, by a trammel constructed for the purpose and by projection from an oblique section of a cylinder or of a cone, each of which will be considered in turn. The ellipse is properly generated from two points upon its major axis, called the foci, and its circumference is so drawn that if from any point therein two lines be drawn to the two foci, their sum shall be equal to the sum of

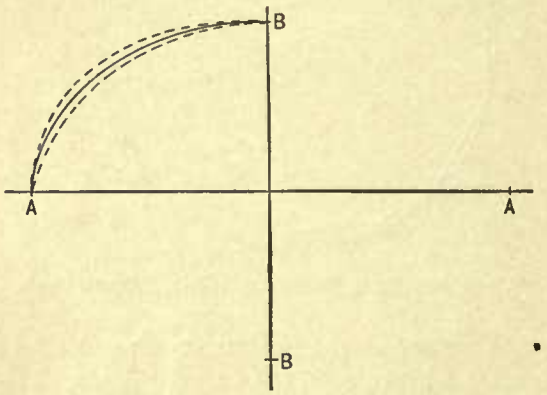


Fig. 206.—Defining an Ellipse.

two lines drawn from any other point in the circumference to the foci.

65. To Draw an Ellipse to Specified Dimensions with a String and Pencil.—In Fig. 207, let it be required to draw an ellipse, the length of which shall be equal to the line A B, and the width of which shall be equal to the line D C. Lay off A B and D C at right angles to each other, intersecting at their middle points, as shown at E. Set the compasses to one-half the length of the required figure, as A E, and from either D or C as center, strike an arc, cutting A B in the points F and G. These points, F and G, then are the two foci, into which drive pins, as shown. Drive a third pin at C. Then pass the string around the three points F, G and C and tie it. Remove the pin C and substituting for it a pencil, pass the same around, as shown at P, keeping the string taut. If the combined lengths from F and G to the several points in the boundary line be set off upon a straight line, their sums will be found equal. For example, the sums of P F and P G, A F and A G, C F and C G, B F and B G, are all the same.

Although correct so far as theory is concerned, this method is liable to error on account of the stretching of the string. The same result can be obtained by means of a trammel constructed for the purpose, which is shown in Fig. 208. E is a section through the arms, showing the groove in which the heads of the bolts move. H and G are the bolts or pins by which the movement is controlled and regulated. In the engraving the bar K is shown with holes at fixed distances, through which the governing pins are passed. An improvement upon this plan of construction consists of a device that will clamp the pins firmly to the bar at any point, thus providing for an adjustment of the most minute variations.

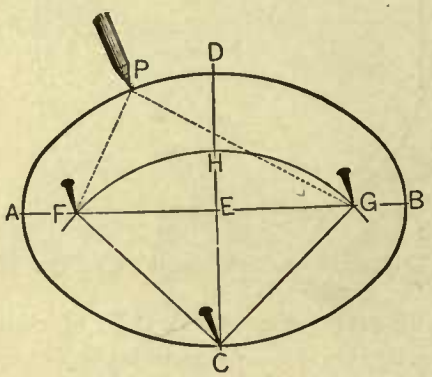


Fig. 207.—To Draw an Ellipse by Means of a String and Pencil.

66. To Draw an Ellipse to Given Dimensions by Means of a Trammel.—In Fig. 208, let it be required to describe an ellipse, the length of which shall be equal to A B and the breadth of which shall be C D. Draw A B and C D at right angles, intersecting at their middle points. Place the trammel, as shown in the engraving, so that the center of the arms shall come directly over the lines. First place the rod along the line A B, so that the pencil or point I shall coincide with either A or B. Then place the pin G directly over the intersection of A B and C D. Next place the rod along the line C D, bringing the pencil or point I to either C or D, and put the pin H over the intersection of A B and C D. The instrument is then ready for use, and the curve is described by the pencil I moved by the hand, and controlled by the pins working in the grooves.

When a trammel is not convenient, a very fair substitute is afforded by the use of a common steel

square and a thin strip of wood, like a lath. This method of drawing an ellipse is useful under ordinary circumstances when only a part of the figure is required, as in the shape of the top of a window frame to which a cap is to be fitted, in which half of the figure would be employed, or in the shaping of a member of a molding in which a quarter, or less than a quarter, of the figure would be used.

67. To Draw an Ellipse of Given Dimensions by Means of a Square and a Strip of Wood.—In Fig. 209, set off the length of the figure, and at right angles to it, through its middle point, draw a line representing the width of the figure. Place a square, as shown by A E C, its inner edge corresponding to the lines. Lay the strip of wood as shown by F E, putting a pencil at the point F, corresponding to one end of the figure, and a pin at E, corresponding to the inner angle of the square. Then place the stick across the figure, as shown in Fig. 210, making the pencil, F, correspond with one side of the figure, and put a pin at G, corresponding with the inner angle of the square. Now move the stick from one position to the other, letting the points E and G slide, one against the tongue and the other against the blade of the square. The pencil point will then describe the required curve. In drawing the figure the square must be changed in position for each quarter of the curve. As shown in the engravings, it is correct for the quarter of the curve represented by F D, Fig. 209. It must be changed for each of the other sections, its inner edge being brought against the lines each time, as shown.

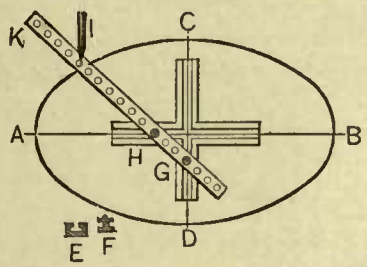


Fig. 208.—To Draw an Ellipse by Means of a Trammel.

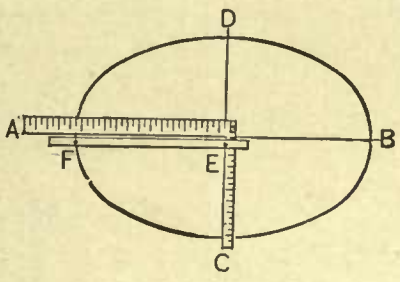


Fig. 209.

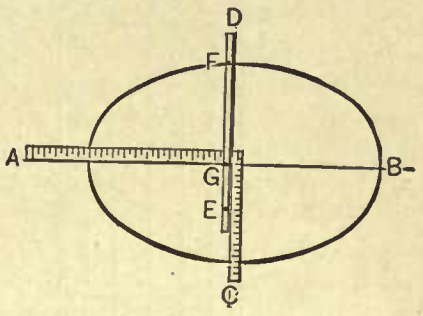


Fig. 210.

To Draw an Ellipse by Means of a Square and a Strip of Wood.

One definition of an ellipse is "a figure bounded by a regular curve, which corresponds to an oblique section of a cylinder."

This can be practically illustrated by assuming a piece of stove pipe as the representative of the cylinder. If the piece of pipe is cut square across, the end placed upon a board, and a line drawn around it, the resulting figure will be a circle. If now the pipe be cut obliquely, as in making an elbow at any angle, and the end thus cut be placed upon a board and a line drawn around it, as mentioned in the first case, the figure drawn will be an ellipse. What has thus been roughly done by mechanical means may be also accomplished upon the drawing board in a very simple and expeditious manner. The demonstration which follows is of especial interest to the pattern cutter, because the principles involved in it lie at the root of many practical operations which he is called upon to perform. For example, the shape to cut a piece to stop up the end of a pipe or tube which is not cut square across, the shape to cut a flange to fit a pipe passing through the slope of a roof, and other similar requirements of almost daily occurrence, depend entirely upon the principles here explained.

68. To Describe the Form or Shape of an Oblique Section of a Cylinder, or to Draw an Ellipse as the Oblique Projection of a Circle.—The two propositions which are stated above are virtually one and the same so far as concerns the pattern cutter, and they may be made quite the same so far as a demonstration is concerned. The explanation of the engraving is confined to the idea of the cylinder, believing it in that shape to be of more practical service to the readers of this book than in any other. In Fig. 211, let G E F H represent any cylinder, and A B C D the plan of the same. Let I K represent the plane of any oblique cut to be made through the cylinder. It is required to draw the shape of the section as it would appear if the cylinder were cut in two by the plane I K, and either piece placed with the end I K flat upon paper and a line scribed around it. Divide one-half of the plan A B C into any convenient number of equal parts, as shown by the figures 1, 2, 3, 4, etc. Through

these points and at right angles to the diameter A C draw lines as shown, cutting the opposite side of the circle. Also continue these lines upward until they cut the oblique line I K, as shown by 1^1, 2^1, 3^1, etc. Draw I^1 K^1, making it parallel to I K for convenience in transferring spaces. With the T-square set at right angles to I K, and brought successively against the points in it, draw lines through I^1 K^1, as shown by 1^2, 2^2, 3^2, etc. With the dividers take the distance across the plan A B C D on each of

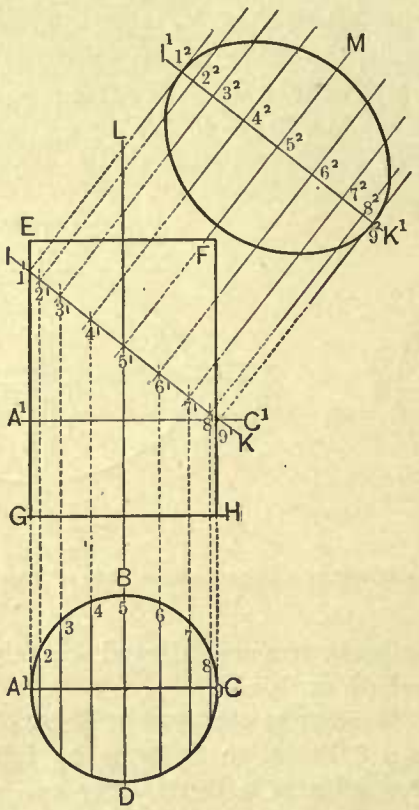


Fig. 211.—The Ellipse as an Oblique Section of a Cylinder.

the several lines drawn through it, and set the same distance off on corresponding lines drawn through I^1 K^1. In other words, taking A C as the base for measurement in the one case and I^1 K^1 as the base of measurement in the other, set off from the latter, on each side, the same length as the several lines measure on each side of A C. Make 2^2 equal to 2, and 3^2 equal to 3, and so on. Through the points thus obtained trace a line, as shown by I^1 M K^1 and the opposite side, thus completing the figure.

To make this problem of practical use it is necessary that the diameter of the cylinder shall be equal to the short diameter of the required ellipse, and that the line I K be drawn at such an angle that the distance 1^1 9^1 shall be equal to its long diameter.

Another definition of the ellipse is that "it is a figure bounded by a regular curve, corresponding to an oblique section of a cone through its opposite sides." It is this definition of the ellipse that classes it among what are known as conic sections. It is generally a matter of surprise to students to find that an oblique section of a cylinder, and an oblique section of a cone through its opposite sides, produce the same figure, but such is the case. The method of drawing an ellipse upon this definition of it is given in the follow-

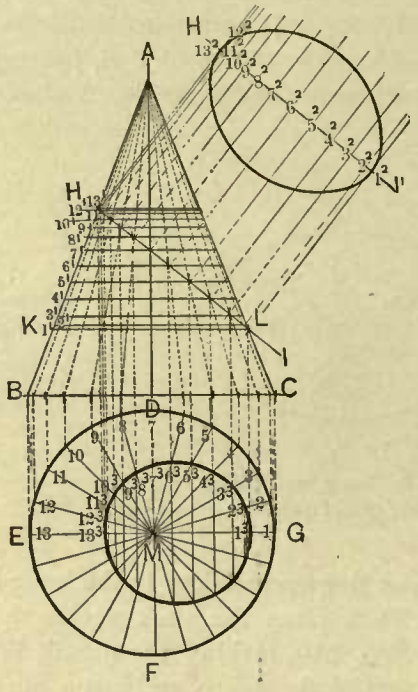


Fig. 212.—The Ellipse as an Oblique Section of a Cone.

ing demonstration. The principles upon which this rule is based, no less than those referred to in the last demonstration, are of especial interest to the pattern cutter, because so many of the shapes with which he has to deal owe their origin to the cone.

69. To Describe the Shape of an Oblique Section of a Cone through its Opposite Sides, or to Draw an Ellipse as a Section of a Cone.—In Fig. 212, let B A C represent a cone, of which E D G F is the plan at the base. Let H I represent any oblique cut through its opposite sides. Then it is required to draw the shape of the section represented by H I, which will be an ellipse. At any convenient place outside of the figure draw a duplicate of H I parallel to it, upon which to construct the figure sought, as H^1 I^1. Divide one-half of the

plan, as E D G, into any convenient number of equal parts, as shown by 1, 2, 3, 4, etc. From the center of the plan M draw radial lines to these points. From each of the points also erect a perpendicular line, which produce until it cuts the base line B C of the cone. From the base line of the cone continue each of these lines toward the apex A, cutting the oblique line H I. Through the points thus obtained in H I, and at right angles to the axis A D of the cone, draw lines, as shown by $1'$, $2'$, $3'$, $4'$, etc., cutting the opposite sides of the cone. From the same points in H I, at right angles to it, draw lines cutting H' I', as shown by 1^2, 2^2, 3^2, 4^2, etc., thus transferring to it the same divisions as have been given to other parts of the figure. After having obtained these several sets of lines, the first step is to obtain a plan view of the oblique cut, for which proceed as follows: With the dividers take the distance from the axial line A D to one side of the cone, on each of the lines $1'$, $2'$, $3'$, $4'$, etc., and set off like distance from the center of the plan M on the corresponding radial lines 1, 2, 3, 4, etc. A line traced through the points thus obtained will give the plan view of the oblique cut, as shown by the inner line in the plan.

This result may be verified by dropping lines vertically from the points in H I across the plan, intersecting them with the radial lines in the plan of corresponding number. Thus a line dropped from point 4 on H I should intersect the radial line M 4 at

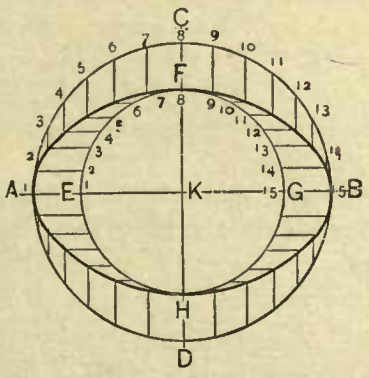


Fig. 213.—To Construct an Ellipse from Two Circles by Intersecting Lines.

the same point (4^2) established upon it by measuring the distance upon line $4'$ from A D to A B. Having thus obtained the shape of the oblique cut as it would appear in plan, the next step is to set off upon the lines previously drawn through H' I' the width of the oblique cut in plan as measured upon lines of corresponding number. Therefore, with E G as a basis of measurement, with the dividers take the distance on each of the several cross lines 2^2, 3^2, 4^2, 5^2, etc., from E G to one side of the plan of the oblique cut just described, and set off the same distance on each side of H' I' on the corresponding lines. A line traced through the points thus obtained will be an ellipse.

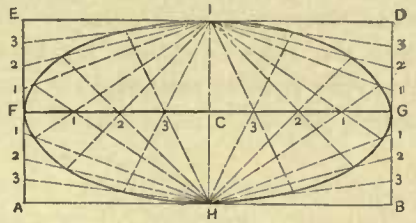


Fig. 214.—To Draw an Ellipse within a Given Rectangle by Means of Intersecting Lines.

70. To Construct an Ellipse to Given Dimensions by the Use of Two Circles and Intersecting Lines.—In Fig. 213, let it be required to construct an ellipse, the length of which shall equal A B and the width of which shall equal H F. Draw A B and H F at right angles, intersecting at their middle points, K. From K as center, and with one-half of the length A B as radius, describe the circle A C B D. From K as center, and with one-half of the width H F as radius, describe the circle E F G H. Divide the larger circle into any convenient number of equal parts, as shown by the small figures 1, 2, 3, 4, etc. Divide the smaller circle into the same number of equal and corresponding parts, as also shown by figures. By means of the T-square, from the points in the outer circle draw vertical lines, and from points in the inner circle draw horizontal lines, as shown, producing them until they intersect the lines first drawn. A line traced through these points of intersection will be an ellipse.

71. To Draw an Ellipse within a Given Rectangle by Means of Intersecting Lines.—In Fig. 214, let E D B A be any rectangle within which it is required to construct an ellipse. Bisect the end A E, obtaining the point F, from which erect the perpendicular F G, dividing the rectangle horizontally into two equal portions. Bisect the side A B, obtaining the point H, and draw the perpendicular H I, dividing the rectangle vertically into two equal portions. The lines F G and H I are then the axes of the ellipse. F G represents the major axis, and H I the minor axis. Divide the spaces F E, F A, G D and G B into any convenient number of equal parts, as shown by the figures 1, 2, 3. From these points in F E and G D draw lines to I, and from the points in F A and G B draw lines to the

point H. Divide F C and G C also into the same number of equal parts, as shown by the figures, and from H and I through each of these points draw lines, continuing them till they intersect lines of corresponding number in the other set, as indicated. A line traced through the several points of intersection between the two sets of lines, as shown in the engraving, will be an ellipse.

Besides the above methods for drawing correct ellipses there are several methods for drawing figures approximating ellipses more or less closely, but com-

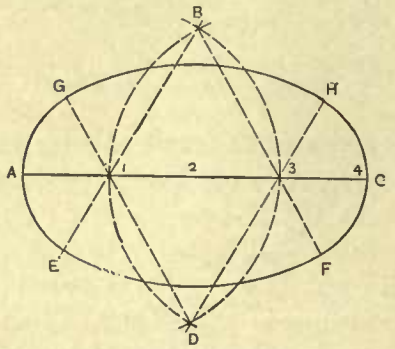


Fig. 215.—First Method.

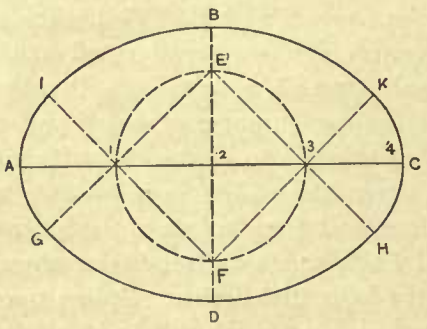


Fig. 216.—Second Method.

To Draw an Approximate Ellipse with the Compasses, the Length only Being Given.

posed of arcs of circles, which it is sometimes necessary to substitute for true ellipses for constructive reasons. The ellipse has been described above as a curve drawn with a constantly changing radius. If, instead of using an infinite number of radii, some finite number be assumed, it will appear that the greater the number assumed the more nearly will it approach a perfect ellipse. Thus, a curve very much like an ellipse can be drawn, each quarter of which is composed of arcs drawn from two centers. If the number of centers be increased to three, the curve comes much nearer a true ellipse, and with four or five centers to each quarter, the curve thus produced can scarcely be distinguished from the perfect ellipse.

72. To Draw an Approximate Ellipse with the Compasses, the Length only being Given.—In Fig. 215, let A C be any length to which it is desired to draw an elliptical figure. Divide A C into four equal parts. From 3 as center, and with 3 1 as radius, strike the arc B 1 D, and from 1 as center, and the same radius, strike the arc B 3 D, intersecting the arc first struck in the points B and D. From B, through the points 1 and 3, draw the lines B E and B F indefinitely, and from D, in like manner, draw the lines D G and D H. From the point 1 as center, and with 1 A as radius, strike the arc E G, and from 3 as center, with the same radius, or its equivalent, 3 C, strike the arc H F. From D as center, with radius D G, strike the arc G H, and from B as center, with the same radius, or its equivalent, B E, strike the arc E F, thus completing the figure.

A figure of different proportions may be drawn in the same general manner as follows: Divide the length A C into four equal parts, as indicated in Fig. 216. From 2 as center, and with 2 1 as radius, strike the circle 1 E 3 F. Bisect the given length A C by the line B D, as shown, cutting the circle in the points E and F. From E, through the points 1 and 3, draw the lines E G and E H indefinitely, and from F, through the same points, draw similar lines, F I and F K. From 1 as center, and with 1 A as radius, strike the arc I A G, and from 3 as center, with equal radius, strike the arc K C H. From E as center, and with radius E G, strike the arc G D H, and from F as center, with corresponding radius, strike the arc I B K, thus completing the figure.

73. To Draw an Approximate Ellipse with the Compasses to Given Dimensions, Using Two Sets of Centers.—*First Method.*—In Fig. 217, let A B represent the length of the required figure and D E its width. Draw A B and D E at right angles to each other, and intersecting at their middle points. At the point A erect the perpendicular A F, and in length make it equal to C D. Bisect A F, obtaining the point N. Draw N D. From F draw a line to E, as shown, cutting N D in the point G. Bisect the line G D by the line H I, perpendicular to G D and meeting D E in the point I. In the same manner draw lines corresponding to G I, as shown by L I, M O and R O. From I and O as centers, and with I G as radius, strike the arcs G D L and M E R, and from K and P as centers,

with K G as radius, strike the arcs G A M and L B R, thus completing the figure.

74. To Draw an Approximate Ellipse with the Compasses to Given Dimensions, Using two Sets of Centers.—*Second Method.*—In Fig. 218, let C D represent the length of a required ellipse and A B the width. Lay off these two dimensions at right angles to each other, as shown. On C D lay off a space equal to the width of the required figure, as shown by D E. Divide the remainder of D C, or the space E C, into three equal parts, as shown in the cut. With a radius equal to two of these parts, and from R as center, strike the circle G S F T. Then with F and G as centers, and F G as radius, strike the arcs, as shown, intersecting upon A B prolonged at O and P. From O, through the points G and F, draw O L and O M, and likewise from center, with F L as radius, describe a circle, as shown, thus establishing the points M, N and O, which, with L, are the centers from which the ellipse is to be struck. From M, draw M L Q and M N S indefinitely, and in a similar manner O L P and O N R. With O as center, and O D as radius, strike the arc P D R, cutting O P and O R, as shown. In a similar manner, and with the same radius (or which is the same, with M E as radius) and M as center, describe the arc Q E S. With L and N as centers, and with L B or N C as radius, strike the arcs Q B P and R C S, thus completing the figure.

The above methods of drawing approximate ellipses are only available within certain limits of proportion, as will be discovered if an attempt is made to draw them very much elongated, the limit being

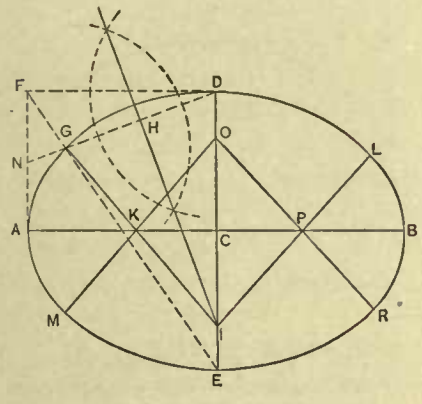


Fig. 217.—First Method.

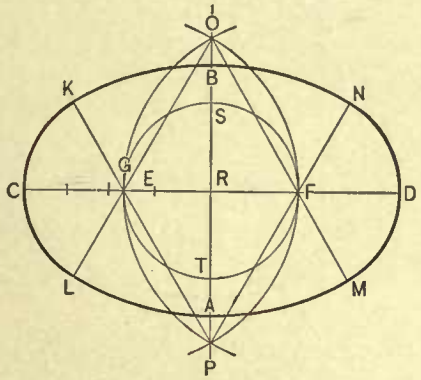


Fig. 218.—Second Method.

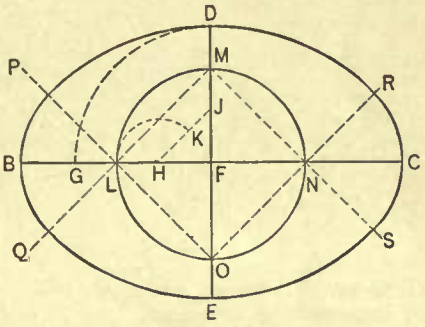


Fig. 219.—Third Method.

To Draw an Approximate Ellipse with the Compasses, Using Two Sets of Centers.

P, through the same points, draw P K and P N. From O as center, with O A as radius, strike the arc L M, and with the same radius, and P as center, strike the arc K N. From F and G as centers, and with F D and G C as radii, strike the arcs N M and K L respectively, thus completing the figure.

75. To Draw an Approximate Ellipse with the Compasses to Given Dimensions, Using Two Sets of Centers.—*Third Method.*—In Fig. 219, let B C represent the length of the required figure and D E its width. B C and D E are drawn at right angles to each other, intersecting at their middle points at F. The next step in describing the figure is to obtain the difference in length between the axes F D and F B, which can be done as indicated by the arc D G. This difference, G B, is to be set off from the center F on F B and F D, as shown by F H, F J, then draw H J and set off half of H J to L, as indicated by the arc K L. The object of the operation so far has been to secure the point L. From F as reached when the long diameter is about equal to two times the shorter diameter. Beyond this limit in the first two methods, if the final arc be drawn with the radius G K (Figs. 217 and 218), it will not reach the end of the long diameter, but will strike it at a point inside of A or C. By the third method, if the long diameter be increased until it is about $2\frac{3}{4}$ times the shorter, the point L (Fig. 219) will fall at the extreme limit of the long diameter (B), thus completely cutting out the small arc P Q. It must, therefore, in extreme cases be left to the judgment of the draftsman to adjust or vary the lengths of the radii of the two arcs so as to produce the result which will look the best.

76. To Draw an Approximate Ellipse with the Compasses to Given Dimensions, Using Three Sets of Centers.—In Fig. 220, let A B represent the length of the required figure and D E the width. Draw A B and D E at right angles to each other, intersecting at their middle points, as shown at C. From the point A draw

A F, perpendicular to A B, and in length equal to C D. Join the points F and D, as shown. Divide A F into three equal parts, thus obtaining the points Z and I, and draw the lines Z D and I D. Divide A C into three equal parts, as shown by Y and G, and draw E G and E Y, prolonging them until they intersect with Z D and I D respectively, in the points J and H. Bisect J D, and draw K L perpendicular to its central point, intersecting D E prolonged in the point L. Draw J L and H J. Bisect H J, and draw M N perpendicular to its central point, meeting J L in N. Draw N H, cutting A B in the point O. L then is the center of the arc J D P, N is the center of the arc H J, and O is the center of the arc H A R. The points S and U, corresponding to N and O, from which to strike the remainder of the upper part of the figure, may be obtained by measurement, as indicated. Having drawn so much of the figure as can be struck from these centers, set the dividers to the distance L P or L J, and placing one point at E, the remaining center will be found at the other point of the dividers, in the line E D prolonged, as shown by X.

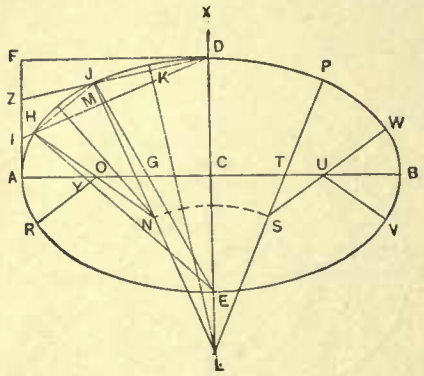


Fig. 220.—To Draw an Approximate Ellipse with the Compasses, Using Three Sets of Centers.

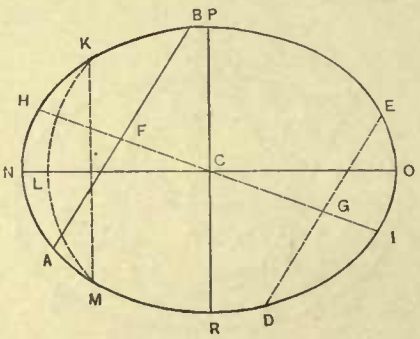


Fig. 221.—To Find the True Axes of a Given Ellipse.

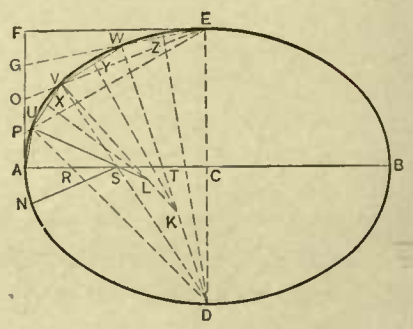


Fig. 222.—In a Given Ellipse, to Find Centers by which an Approximate Figure may be Constructed.

77. To Find the True Axes of a Given Ellipse.—In Fig. 221, let N P O R be any ellipse, of which it is required to find the two axes. Through the ellipse draw any lines, A B and D E, parallel to each other. Bisect these two lines and draw F G, prolonging it until it meets the sides of the ellipse in the points H and I. Bisect the line H I, obtaining the point C. From C as center, with any convenient radius, describe the arc K L M, cutting the sides of the ellipse at the points K and M. Join K and M by a straight line, as shown. Bisect M K by the line N O, perpendicular to it. Through C, which will also be found to be the center of N O, draw P R, perpendicular to N O and parallel to K M. Then N O and P R are the axes of the ellipse.

78. In a Given Ellipse, to Find Centers by which an Approximate Figure may be Constructed.—In Fig. 222, let A E B D be any ellipse, in which it is required to find centers by which an approximate figure may be drawn with the compasses. Draw the axes A B and E D. From the point A draw A F, perpendicular to A B, and make it equal to C E. Join F and E. Divide A F into as many equal parts as it is desired to have sets of centers for the figure. In this instance four. Therefore, A F is divided into four equal parts, as shown by P O and G. Divide A C into the same number of equal parts, as shown by R S T. From the points of division in A F draw lines to E. From D draw lines passing through the divisions in A C, prolonging them until they intersect the lines drawn from A F to E, as shown by D U, D V and D W. Draw the chords U V, V W and W E, and from the center of each erect a perpendicular, which prolong until they intersect as follows: The line perpendicular to W E intersects the center line E D in the point D. Now draw D W and prolong the perpendicular to V W till it intersects D W in K, and draw K V. Prolong the perpendicular to U V till it cuts K V in L and draw L U, cutting A C in the point S. Then D is the center of the arc E W, K is the center of the arc W V, L is the center of the arc V U and S is the center of the arc U N. By these centers it will be seen that one-quarter of the figure (A to E) may be struck. By measurement, corresponding points may be located in other portions of the figure. If correctly done the points U, V and W

will be found to fall upon the ellipse, consequently the arcs drawn between those points from the centers obtained cannot deviate much from the correct ellipse.

79. To Draw the Joint Lines of an Elliptical Arch.—*First Method.*—In a circular arch the lines representing the joints between the stones forming the arch, or the voussoirs as they are properly called, are drawn radially from the center of the semicircle of the arch. In an elliptical arch this operation is somewhat more difficult as the true ellipse possesses no such single

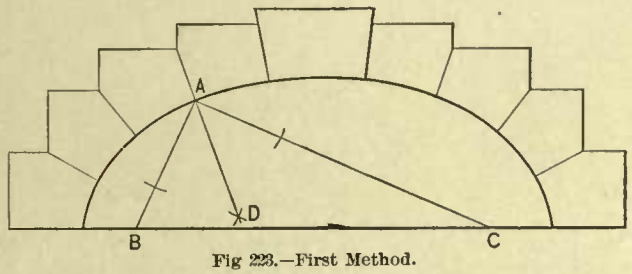


Fig 223.—First Method.
To Draw the Joint Lines of an Elliptical Arch.

point, but, instead, two foci, as has been explained. Therefore, the following course must be pursued: From any point upon the ellipse at which it is desired to locate a joint, as A, Fig. 223, draw a line to each of the foci, as A B and A C. Bisect the angle B A C (Prob. 12 in this chapter), as shown at D, and extend the line D A outside the ellipse, which will be the joint line required.

80. To Draw the Joint Lines of an Elliptical Arch.—*Second Method.*—In Fig. 224, A B is one-half the curve of the arch, A C its center line and C B its springing line. Draw A D parallel to C B, and D B parallel to A C, and draw the diagonals A B and C D. From each of the points 1, 2, 3, etc., representing the joints, drop lines vertically, cutting C D. From their intersections with C D carry them at right angles to A B, cutting the springing line C B, as shown by the small figures 1^2, 2^2, 3^2, etc. From the points in C B draw

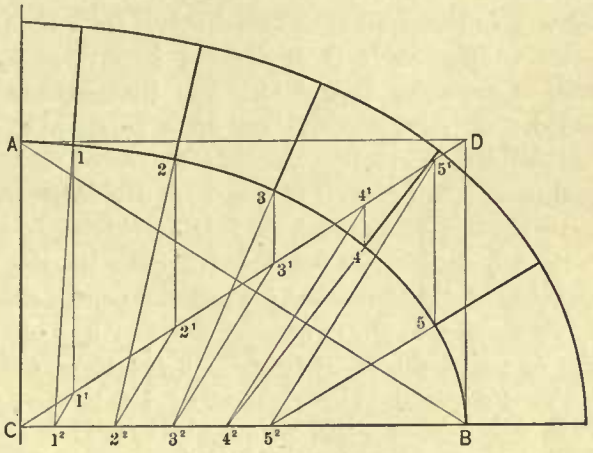


Fig. 224.—Second Method.
To Draw the Joint Lines of an Elliptical Arch.

lines through corresponding points in the arch A B, as 1^2 1, 2^2 2, 3^2 3, etc., and continue them through the face of the arch which will be the joint lines sought.

In the case of an elliptical curve made up of arcs of circles, the joint lines would be drawn radially from the centers of the arcs in which they occur.

THE VOLUTE.

The volute is an architectural figure of a geometrical nature based upon the spiral, and is of quite frequent occurrence in one form or another, consequently some remarks upon the different methods of drawing it will not be out of place.

81. To Draw a Simple Volute.—Let D A, in Fig. 225, be the width of a scroll or other member for which it is desired to draw a volute termination. Draw the line D 1, in length equal to three times D A, as shown by D A, A B and B 1. From the point 1 draw 1 2 at right angles to D 1, and in length equal to two-thirds the width of the scroll—that is, to two-thirds of D A. From 2 draw the line 2 3 perpendicular to 1 2, and in length equal to three-quarters of 1 2. Draw the diagonal line 1 3. From 2 draw a line perpendicular to 1 3, as shown by 2 4, indefinitely. From 3 draw a line perpendicular to 2 3, producing it until it cuts the line 2 4 in the point 4. From 4 draw a line perpendicular to 3 4, producing it until it meets the line 1 3 in the point 5. In like manner draw 5 6 and 6 7. The points 1, 2, 3, 4, etc., thus obtained are the centers by which the curve of the volute is struck. From 1 as center, and with 1 D as radius, describe the quarter circle D C. Then from 2 as center, and 2 C as radius, describe the quarter circle C F, and so continue using the centers in their numerical order until the curve intersects with the other curve beginning at A and struck from the same centers, thus completing the figure, as shown.

82. To Draw an Ionic Volute.—Draw the line A B, Fig. 226, equal to the hight of the required volute, and divide it into seven equal parts. From the third division draw the line 3 C, and from a point on this line at any convenient distance from A B describe a

circle, the diameter of which shall equal one of the seven divisions of the line A B. This circle forms the eye of the volute. In order to show its dimensions, etc., it is enlarged in Fig. 227. A square, D E F G, is constructed, and the diagonals G E and F D are drawn. F E is bisected at the point 1, and the line 1 2 is drawn parallel to G E. The line 2 3 is then drawn indefinitely from 2 parallel to F D, cutting G E in the point H. The distance from H to the center of the circle O is divided into three equal parts, as shown by H *a b* O. The triangle 2 O 1 is formed. On the line O H set off a point, as *c*, at a distance from O equal to one-half of one of the three equal parts into which O H has been divided. From *c* draw the line *c* 3 parallel to 1 O, producing it until it cuts 2 3 in the point 3. From 3 draw the line 3 4 parallel to G E indefinitely. From the point *c* draw a line *c* 4 parallel to 2 O, cutting the line 3 4 in the point 4, completing the triangle *c* 3 4. From 4 draw the line 4 5 parallel to F D, meeting 1 O in the point 5. From 5 draw the line 5 6 parallel to G E, meeting the line 2 O in the point 6. From 6 draw the line 6 7 parallel to F D, meeting the line *c* 3 in the point 7.

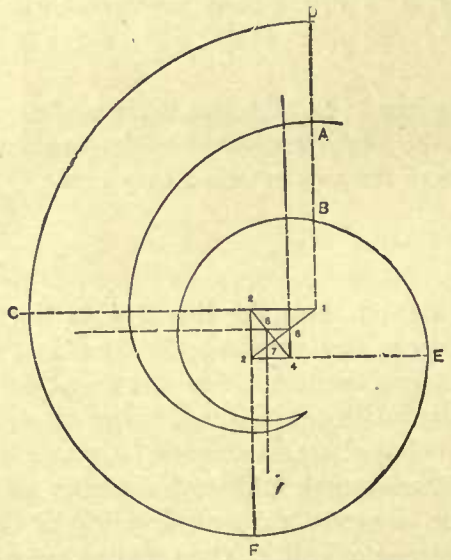


Fig. 225.—To Draw a Simple Volute.

Proceed in this manner, obtaining the remaining points, 8, 9, 10, 11 and 12. These points form the centers by which the outer line of the volute proper is drawn. From 1 as center, and with radius 1 F, Fig. 226, describe the quarter circle F G. Then from 2 as center, and with radius 2 G describe the quarter circle G D, and so continue striking a quarter circle from each of the centers above described until the last arc meets the circle first drawn. To obtain the centers by which the inner line of the volute is struck, and which gradually approaches the outer line throughout its course, proceed as follows: Produce the line 3 *c*, Fig. 227, until it intersects 1 2 in the point 1^1, which

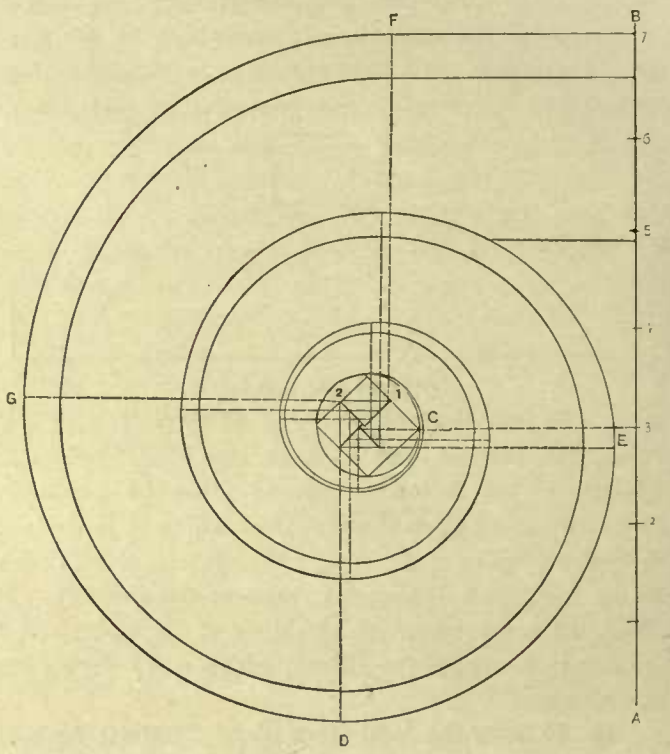


Fig. 226.—To Draw an Ionic Volute.

mark. This operation gives also the points 9^1 and 5^1 of intersection with the lines parallel to 1 2, which also mark. In like manner produce 4 *c*, 1 O and 2 O, as shown by the dotted lines, and mark the several points of intersection formed with the cross lines. Then the points 1^1, 2^1, 3^1, 4^1, etc., thus obtained are the centers for the inner line of the volute, which use in the same manner as described for producing the outer line.

83. To Draw a Spiral from Centers with Compasses.—Divide the circumference of the primary—sometimes called the eye of the spiral—into any number of equal parts; the larger the number of parts the more regular will be the spiral. Fig. 228 shows the primary divided into six equal parts. Fig. 229 is an enlarged view of this portion of the preceding figure. Construct the polygon by drawing the lines 1 2, 2 3, 3 4, etc., producing them outside of the primary, as shown by A, B, D, F, C and E. From 2 as center, with 2 1 as radius, describe the arc A B. From 3 as center, and 3 B as radius, describe the arc B D; and

with 4 as center, with radius 4 D, describe the arc D F. In this manner the spiral may be continued any number of revolutions. In the resulting figure the various revolutions will be parallel.

84. To Draw a Spiral by Means of a Spool and Thread.—Set the spool as shown by A D B in Fig.

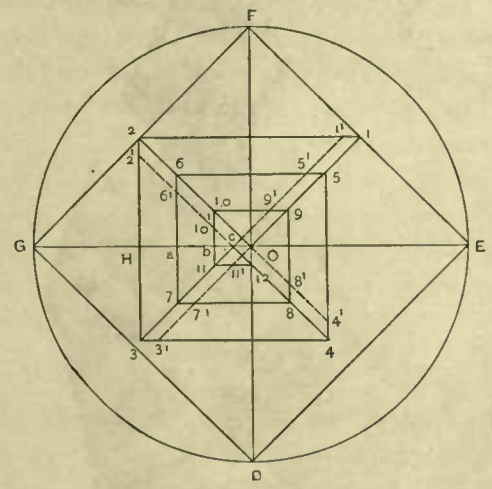


Fig. 227.—Eye of the Volute in Fig. 226 Enlarged.

230 and wind a thread around it. Make a loop, E, in the end of the thread, in which place a pencil, as shown. Hold the spool firmly and move the pencil around it, unwinding the thread. A curve will be described, as shown in the dotted lines of the engraving. It is evident that the proportions of the figure are determined by the size of the spool. Hence a larger or smaller spool is to be used, as circumstances require.

85. To Draw a Scroll to a Specified Width, as for a Bracket or Modillion.—In Fig. 231, let it be required to construct a scroll which shall touch the line D B at the top, E A at the bottom and A B at the side, the length of A B, which determines the width of the scroll, being given. Bisect A B, obtaining the point C. Let the distance between the beginning and ending of the first revolution of the scroll, shown by *a e*, be established at pleasure. Having determined

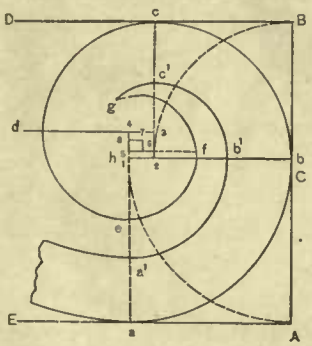


Fig. 231.—To Draw a Scroll to a Specified Width.

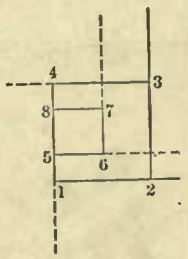


Fig. 232.—The Center of Fig. 231 Enlarged.

this distance, take one-eighth of it and set it off upward from C on the line A B, thus obtaining the point *b*. From *b* draw a horizontal line of any convenient length, as shown by *b h*. With one point of the compasses set at *b*, and with *b* A as radius, describe an arc cutting the line *b h* in the point 1. In like manner, from the same center, with radius *b* B, describe an arc cutting the line *b h* in the point 2. Upon 1 2 as a base erect a square, as shown by 1 2 3 4. Then from 1 as center, with 1 *a* as radius, describe an arc, *a b*; and from 2 as center, with 2 *b* as radius, describe the arc *b c*. From 3 as center, with radius 3 *c*, describe the arc *c d*. From 4 as center, with radius 4 *d*, describe the arc *d e*. If the curve were continued from *e*, being struck from the same centers, it would run parallel to

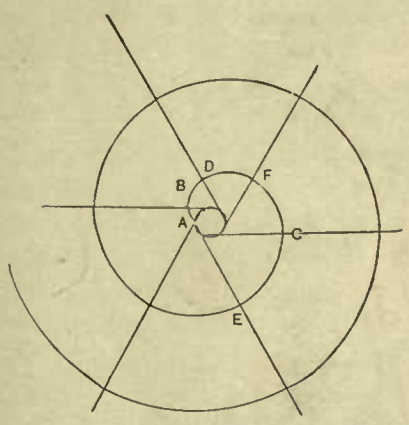


Fig. 228.—To Draw a Spiral from Centers.

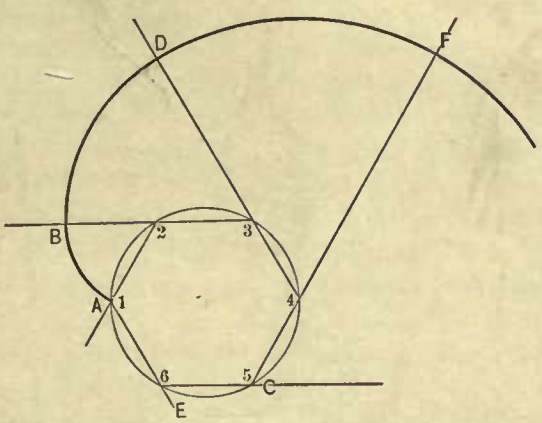


Fig. 229.—Enlarged View of the Eye of the Spiral in Fig. 228.

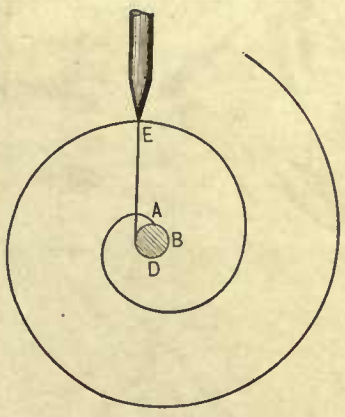


Fig. 230.—To Draw a Spiral by Means of a Spool and Thread.

itself; but as the inner line of the scroll runs parallel to the outer line, its width may be set off at pleasure, as shown by $a\ a^1$, and the inner line may be drawn by the same centers as already used for the outer, and continued until it is intersected by the outer curve. To find the centers from which to complete the outer curve, construct upon the line of the last radius above used (4 *e*) a smaller square within the larger one, as shown by 5 6 7 8. This is better illustrated by the larger diagram, Fig. 232, in which like figures represent the same points. Make the distance from 5 to 8 equal to one-half of the space from 4 to 1, making 4 to 8 equal the distance of 5 to 1. Make 5 to 6 equal the distance from 8 to 5. After obtaining the points 5, 6, 7, etc., in this manner, so many of them are to be used as are necessary to make the outer curve intersect the inner one, as shown at *g*. Thus 5 is used as a center for the arc *e f*, and 6 as a center for the arc *f g*. If the distance $a\ a^1$ were taken less than here given, it is easy to see that more of the centers upon the small square would require to be used to arrive at the intersection.

CHAPTER V.

Principles of Pattern Cutting.

To any one wishing to pursue pattern cutting as a profession it is essential not only that he know how to solve a large number of intricate problems, but that he understand thoroughly the principles which underlie such operations. It is, therefore, appropriate, before introducing pattern problems, that some attention should be given to the explanation of such principles in order that the reasons for the steps taken in the demonstrations following may be readily understood. Underlying the entire range of problems peculiar to sheet metal work are certain fundamental principles, which, when thoroughly understood, make plain and simple that which otherwise would appear arbitrary, if not actually mysterious. So true is this that nothing is risked in asserting that any one who thoroughly comprehends all the steps in connection with cutting a simple square miter is able to cut any miter whatsoever. Since almost any one can cut a square miter, the question at once arises, in view of this statement, why is it that he cannot cut a raking miter, or a pinnacle miter, or any other equally difficult form? The answer is, because he does not understand how he cuts the square miter. He may perform the operation just as he has been taught, and produce results entirely satisfactory from a mechanical standpoint, without being intelligent as to all that he has done. He does not comprehend the why and wherefore of the steps taken. Hence it is that when he undertakes some other miter he finds himself deficient.

There is a wide difference between the skill that produces a pattern by rote—by a mere effort of the memory—and that which reasons out the successive steps. One is worth but very little, while the other renders its possessor independent. It is with a desire to put the student in possession of this latter kind of skill, to render him intelligent as to every operation to be performed, that the present chapter is written.

The forms with which the pattern cutter has to deal may be divided, for convenience of description, into three general classes:

I. The first of these embraces moldings, pipes and *regular continuous forms*, and may be called forms of parallel lines, or as a shorter and more convenient name to use, **parallel forms.**

II. The second, which will be called **regular tapering forms,** comprehends all shapes derived from cones or pyramids, or from solids having any of the regular geometric figures as a base and which terminate in an apex.

III. The third class will be called **irregular forms,** and will include everything not classified under either of the two previous heads. Many of these might be properly called *transition* pieces—that is, pieces which have figures of various outlines placed at various angles as their bases, and have figures with differing outlines variously placed, as their upper terminations, thus forming transitions, or connecting pieces between the form which lies next them at one end and the adjacent form on the other end.

While pieces of metal of any shape necessary to form the covering of a solid of any shape may properly be called *patterns*, the shapes of pieces necessary to form the joints between moldings meeting at an angle are known distinctively as *miters*. This name applies equally well in sheet metal work if the two arms of the molding are not of the same profile, or to a single arm coming against any plain or irregular surface. These forms comprise the first class referred to above and, so far as principle is concerned, come under the same general rules, which will be subsequently given.

Conical forms, with very little taper, coming against other forms are also said to miter with them. In fact, the word miter has come into such general use that it is often applied to any joint between pieces of metal; but the term can scarcely be considered as correct when the forms have very much taper. The principle involved in the development of such patterns, however, is the same as that applied to the development of the surfaces of all other *regular tapering forms*,

referred to above as the second class, whose characteristics will be considered in their proper chapter.

The method employed for developing the patterns for forms of the third class has been termed *triangulation*, and is adopted on account of its simplicity, as it does away with the reduction or subdivision of an irregular form into a number of smaller regular forms, each one of which would have to be treated separately and perhaps by a different method. In fact, there are some shapes which have arisen from force of circumstances which it would be impossible to separate into regular parts, and even if they could be so separated such a course would result in tedious and complicated operations.

After principles have been thoroughly explained the problems in this work will follow in three sections or departments of the final chapter, arranged according to the above classification.

This is one of the instances in which the pattern cutter is required to be something of an architectural draftsman, and to this end a chapter on Linear Drawing (Chap. III) has been introduced, in which attention is given to this phase of the work, and to which the student is referred.

The arrangement of the problems in each of the sections of the succeeding chapter will be made with reference to these two conditions, the simpler ones being placed before those in which preliminary drawing is required.

Parallel Forms.

(MITER CUTTING.)

Since in sheet metal work a molding is made by bending the sheet until it fits a given stay, a molding may be defined mechanically as a succession of parallel forms or bends to a given stay, and, so far as the mechanic is concerned, any continuous form or arrangement of parallel continuous forms, made for any purpose whatever, may be considered a molding and treated under the same rules in all the operations of pattern cutting. Keeping this fact in mind all parallel forms will be considered as moldings and that word will be used in the demonstrations, remembering that a difference in name simply means a difference of profile, but not a difference in treatment or principle.

Fig. 233.—Profile of a Molding.

Fig. 234.—A Stay.

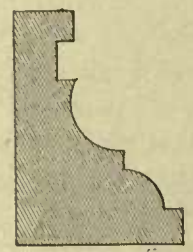


Fig. 235.—A Reverse Stay.

Two conditions exist in regard to the work of developing patterns of all forms, no matter to which of the three classes above defined they may belong:

First—In very many cases a simple elevation or plan of the intersecting parts, together with their profiles, is all that is necessary to begin the work of developing the pattern—that is, the plan or elevation, as the case may be, shows the line (either straight or curved) which represents the surface against which another part is to be fitted; in other words, the much sought for "miter line."

Second—In numerous other instances, however, no view can be drawn either in elevation, oblique or otherwise, or in plan, in which the miter or junction of the parts will appear as a simple straight or curved line against which the points can be dropped. In such cases it becomes necessary to do some preliminary work in order to prepare the way to the actual work of laying out the pattern. A view of the joint must be developed by means of intersections of lines which will show it as it appears in connection with the elevation or plan to be used in developing the pattern.

A molding may be defined theoretically as a form or surface generated by a profile passed in a straight or curved line from one point to another, this profile being the shape that would be seen when looking at its end if the molding were cut off square. A practical illustration of this may be given as follows: In Fig. 233, let the form shown be the profile of some molding. If this shape be cut out of tin plate or sheet iron, as shown in Fig. 234, it is called a stay. For the purpose of this illustration, as will appear further on, a stay, the reverse of the one shown in Fig. 234, or, in other words, the piece cut from the face or

outside of the shape represented in that figure, as shown in Fig. 235, will be required.

Having made a reverse stay, or "outside stay," as it is sometimes called, Fig. 235, take some plastic material—as potters' clay—and, placing it against any smooth surface, as of a board, place the stay against the board near one end in such a position that its vertical lines are parallel with the ends of the board, and move this reverse stay in a straight line along the face of the board until a continuous form is obtained in the clay corresponding to the profile of the stay, all as illustrated in Fig. 236. By this operation will be produced a molding in accordance with the second definition above given. The purpose in introducing this illustration is to show more clearly than is otherwise possible the principles upon which the different parts of a molding are measured in the process of pattern cutting.

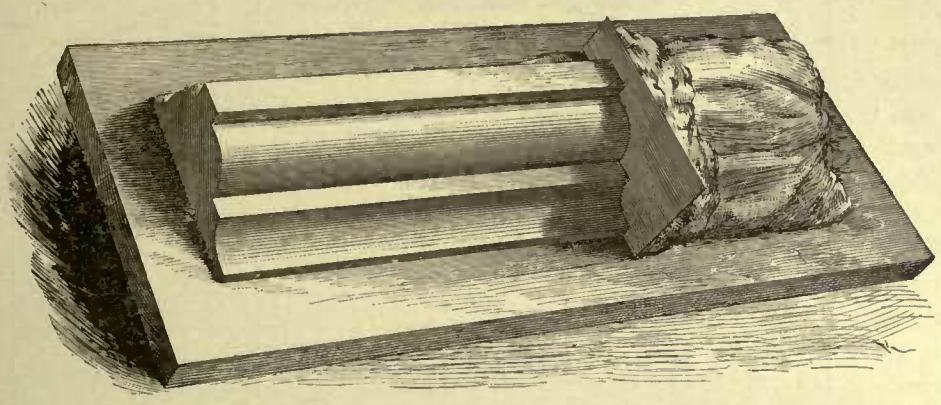


Fig. 236.—Generating a Molding in Plastic Material by Means of a Reverse Stay.

Suppose that the form produced as illustrated in Fig. 236 be completed, and that both ends of the molding be cut off square. It is evident, upon inspection, that the length of a piece of sheet metal necessary to form a covering to this molding will be the length of the molding itself, and that the width of the piece will be equal to the distance obtained by measuring around the outline of the stay which was used in giving shape to the molding. Now with a thin-bladed knife, or by means of a piece of fine wire stretched tight, let one end of the clay molding just constructed be cut off at any angle. By inspection of the form when thus cut, as clearly shown in the upper part of Fig. 237, it is evident that the end of a pattern to form a covering of this model must have such a shape as will make it when formed up conform to the oblique end of the molding or model.

To cut such a pattern by means of a straight line drawn from a point corresponding to the end of the longer side of the mold, to a point corresponding to the end of the shorter side of it, would not be right, evidently, because certain parts of the covering, when formed up, fold down into the angles of the molding, and therefore would require to be either longer or shorter, as the case might be, than if cut as above described. It is plain, then, that some plan must be devised by which measurements can be taken in all these angles or bends, and at as many intermediate points as may be necessary, in order to obtain the right length at all points throughout its width. This can be done quite simply as follows:

Divide the curved parts of the stay into any convenient number of equal parts, and at each division cut a notch, or affix a point to it. Replace the stay in the position it occupied in producing the molding shown in Fig. 236 and pass it again over the entire length of the model. The points fastened to the stay will then leave tracks or lines upon the surface of the molding. Now, by means of measurement upon the different lines thus produced, the length of the molding at all of the several points established in the stay may be obtained. All this is clearly illustrated in Fig. 237. In the upper right hand corner of the illustration is shown the stay prepared with points, by moving which as above described lines are left upon the face of the molding, as shown to the left

Now, upon a sheet of paper fastened to a drawing board, draw a vertical line, as shown by A B in Fig. 237, and upon that line set off with the dividers the width of each space or part of the profile or stay—that is, make the space 1 2 in the line A B equal to the space 1 2 in the stay, and 2 3 in the line A B equal to 2 3 of the stay, and so continue until all the spaces are transferred—and from the points thus obtained in A B draw lines at right angles to it indefinitely, as shown to the left. The lines an dspaces upon the paper will then correspond to the lines and spaces upon the clay molding made by the points fastened to the stay. Next, measure with the dividers the length of the molding upon each of the lines drawn upon it, and set off the same lengths upon the corresponding

lines drawn upon the paper. This gives a series of points through which a line may be traced which will correspond in shape to the oblique end of the molding. Thus, set off from A B on the line 1 on the paper the length of the molding, measured from its straight end to its oblique end, upon the line produced by point 1 of the stay upon its face: and upon each of the other lines on the paper set off the length of the molding on the corresponding line on its face, measuring from the square end each time, which is represented by the line A B of the drawing. By this means are obtained points through which, if a line be traced, as shown by C D, the pattern of the covering will be described. The line A B, containing measurements from the profile, is called the "stretchout line," and the lines drawn through the points in it and at right angles to it are mathematically known as ordinates, but will in this work be called "measuring lines."

Now, what has been done in Fig. 237 illustrates what is called "miter cutting," which in other words consists in describing upon a flat surface the shape of a given form or envelope, so that when the envelope is cut out of the flat surface and formed up to the stay from which its stretchout was derived, the finished molding will fit against a given surface at a given angle previously specified.

The pattern shown in the lower part of Fig. 237, which has been obtained by means of a clay model, and measurements for which were obtained from the lines drawn on the surface of the clay model—may be obtained just as well from a drawing. The question then is, how can the same results be obtained by lines drawn upon a flat surface as were obtained by measurements on lines drawn along the surface of a molding?

In moving the stay along the clay molding, certain lines were made by means of the points affixed. If the reader will carefully examine Fig. 237 he will notice that the lines upon the molding made by this means corresponded in number and position with the points in the profile when it is laid flat on its side, in a position exactly opposite the end of the model, as shown.

Hence, if the profile be drawn upon paper and in line with it, the elevation terminated by the oblique line, which represents the surface against which it is required to miter, the same results can be accomplished, care only being necessary that the relative positions of the parts be correctly maintained.

This is illustrated in Fig. 238, which is to be compared with Fig. 237, and shows: First, that the profile A is drawn in correct position. Next, that from it the elevation F C D G of the molding is projected, as follows: Use the T-square in the general position shown by B in the engraving, bringing it against the several points in A in order to draw the lines. Draw a line for each of the angles in the profile A, and also one corresponding to each of the intermediate points in the curved parts of the stay. Draw the line F G, representing the oblique cut, and the line C D, representing the straight end. Then it will be seen that F C D G of Fig. 238, so far as lines are concerned, is exactly the same as the molding made of clay, shown in Fig. 237. The line F G, by the definition of a miter, is the "miter line" of this

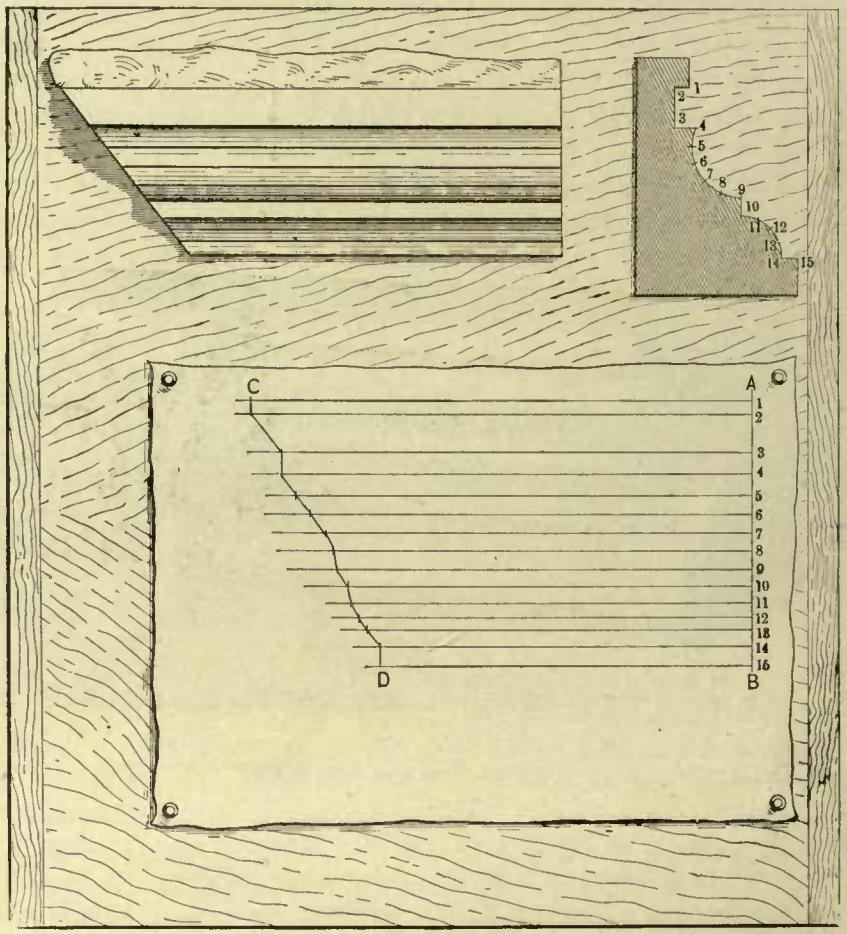


Fig. 237.—The Use of Lines in Obtaining the Envelope of a Molding from a Model of the Same.

molding. It represents the surface against which the end of the molding is supposed to fit. Next lay off a stretchout of the profile A, in the same manner as described in connection which Fig. 237, all as shown by H K in Fig. 238, through the points in which draw measuring lines at right angles to it, or, what is the same, parallel to the lines of the moldings. Now, make each of these lines equal in length to the line of corresponding number drawn across the elevation from C D to F G.

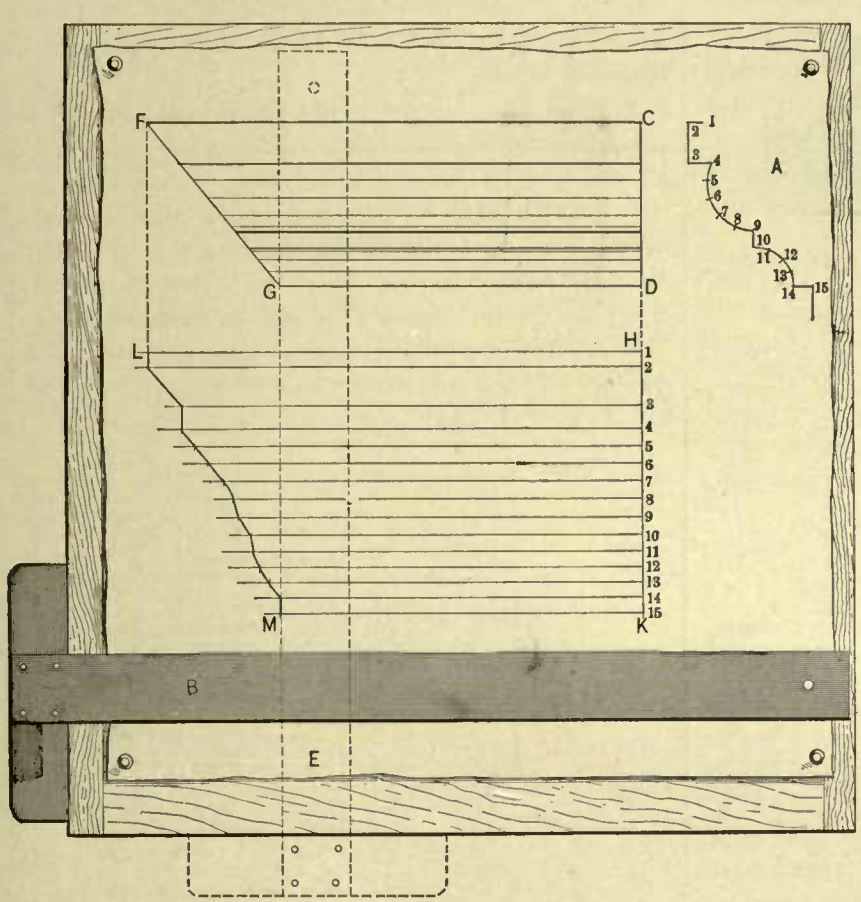


Fig. 238.—Obtaining the Envelope of a Molding from a Drawing of the Same by the Use of the T-Square.

If, as suggested in the previous illustration—that is, by using a pair of dividers to measure the length of the molding from C D to F G on the several lines—these lengths be set off on corresponding lines drawn from the stretchout line H K, a pattern will be obtained in all respects corresponding to the pattern shown in Fig. 237, already referred to. By inspection of the result thus obtained, however, it will be seen that each point in L M is directly under the point of corresponding number in line F G, and that the same thing may be accomplished by using the T-square placed in the position shown by the dotted lines in Fig. 238. Therefore, instead of using the dividers proceed as follows: Place the T-square as shown at E, and, bringing it successively against the points in F G, cut measuring lines of corresponding number by means of a dot or short dash placed across the line. Then a line traced as before through the points of intersection thus obtained, as shown from L to M, will be the shape of the pattern necessary to make it fit against a surface placed at the angle represented by the miter line F G. By this illustration it is shown that the T-square may be used with great advantage in transferring measurements under almost all circumstances. Since now the T-square is to be used instead of the dividers to locate the points in the patterns, the stretchout line is not needed as a starting point from which to measure lengths and may, therefore, be located at will. For convenience, it should be placed as near to the miter line as possible. Hence, in practical work, supposing that the molding represented by F C D G is not a very short piece, the stretchout line, instead of being opposite the end C D, would be placed somewhere near the line of the blade of the T-square when in its position at E. Should the arm required be short, a line drawn opposite the square end will serve the double purpose of a stretch-out line and of the outline of the square end of the pattern.

By further inspection of Fig. 238, it will be seen that, instead of drawing the lines from the points in the profile A the entire length of the molding, as there shown, all that is necessary to the operation is a short line corresponding to each of the points of the profile, extending only across the miter line F G. The use of these lines, it is evident, is only to locate intersections upon the miter line. In other words, all that is needed is the points in the profile A transferred to the miter line F G. The operation of transferring these points by short lines, as above described, is termed "dropping the points" from the profile to the miter line.

If, instead of the molding terminating against a plane surface, as shown by F G in Fig. 238, it be required to develop a pattern to fit against an irregular

surface, the method of procedure would be exactly the same, simply substituting for the straight line F G a representation of that surface. From this it will be seen that all that is required to develop the pattern of any miter is that a correct representation (elevation or plan) of the molding be made, showing the angle of the miter, and that a profile be so drawn that it shall be in line with the elevation of the molding—its face

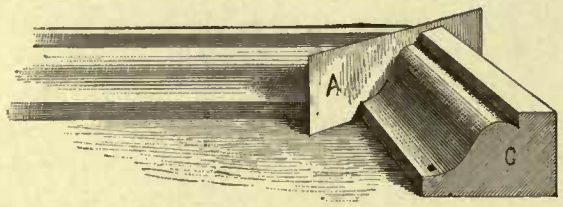


Fig. 239.—Comparison Between a Butt Miter and a Miter Between Two Moldings at Any Angle.

being so placed as to agree with the face of the molding—and that points from the subdivisions of the profile be carried parallel to the molding, their intersections with the miter line being marked by short lines.

In order to more clearly indicate the point desired by this summary of requirements, suppose that upon each of two pieces of molding made of wood, miters at the same angle be cut (right and left) by means of a saw, and that they be then placed together, as shown in Fig. 239. Now, if a piece of sheet iron, for example, be slipped into the joint, as shown by A, and then one arm of the miter be removed what is left will be exactly what is shown in Fig. 238. In other words, a miter between two straight pieces of molding of the same profile is exactly the same as a miter of the same mold against a plane, and, hence, the operation of cutting the pattern in such a case as shown in Fig. 239 is identical with that described in Figs. 237 and 238.

From this it is plain to be seen that the central idea in miter cutting is to bring the points from the profile against the miter line, no matter what may be its shape or position, and from the miter line into a stretch-out prepared to receive them. Inasmuch as all moldings, if they do not member or miter with duplicates of themselves, must either terminate square or against some dissimilar profile, it follows that the two illustrations given cover in principle the entire catalogue of miters.

The principles here explained are the fundamental principles in the art of pattern cutting, and their application is universal in sheet metal work. It would be difficult to compile a complete list of miter problems. New combinations of shapes and new conditions are continually arising. The best that can be done, therefore, in a book of this character, is to present a selection of problems calculated to show the most common application of principles which, carefully studied, will so familiarize the student with them that he will have no difficulty afterward in working out the patterns for whatever shapes may come up in his practice, whether they be of those specifically illustrated or not.

From the foregoing the following summary of requirements, together with a general rule for cutting all miters whatsoever, are derived:

Requirements.—There must be a plan, elevation or other view of the shape, showing the line of the joint or surface against which it miters, in line with which must be drawn a profile or sectional view of same, and this profile must be prepared for use by having all its curved portions divided into such a

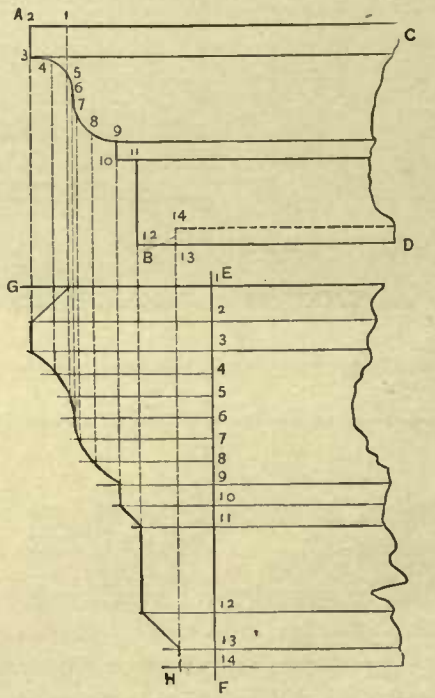


Fig. 240.—Usual Method of Cutting a Square Return Miter.

number of spaces as is consistent with accuracy and convenience.

It may be remarked here that the division of the profile into spaces is only an approximate method of obtaining a stretch-out. As theoretically the straight distance from one of the assumed points to another upon a curved line is less than the distance measured around the curve, and the shorter the radius of the

curve the greater is this difference (a chord is less than the arc which it subtends,) hence the greater the number of points assumed the greater will be the accuracy, and a curve of short radius should be divided more closely than one of longer radius. The profile thus represents practically a succession of plane surfaces.

Rule.—1. Place a stretch-out of the profile on a line at right angles to the direction of the molding, as shown in the plan, elevation or other view, through the points in which draw measuring lines parallel to the molding. 2. Drop lines from the points in the profile to the miter line or line of joint, carrying them in the direction of the molding till they intersect said line. 3. Drop lines from the intersections thus obtained with the miter or joint line on to the measuring lines of the stretch-out, at right angles to the direction of the molding.

In making the application of this rule the student must not forget that the word profile covers a vast range of outlines, varying from a simple straight line to an entire section of a roof or even more, where large curved surfaces are to be treated, and that a rule that applies to one can be applied to the others equally well.

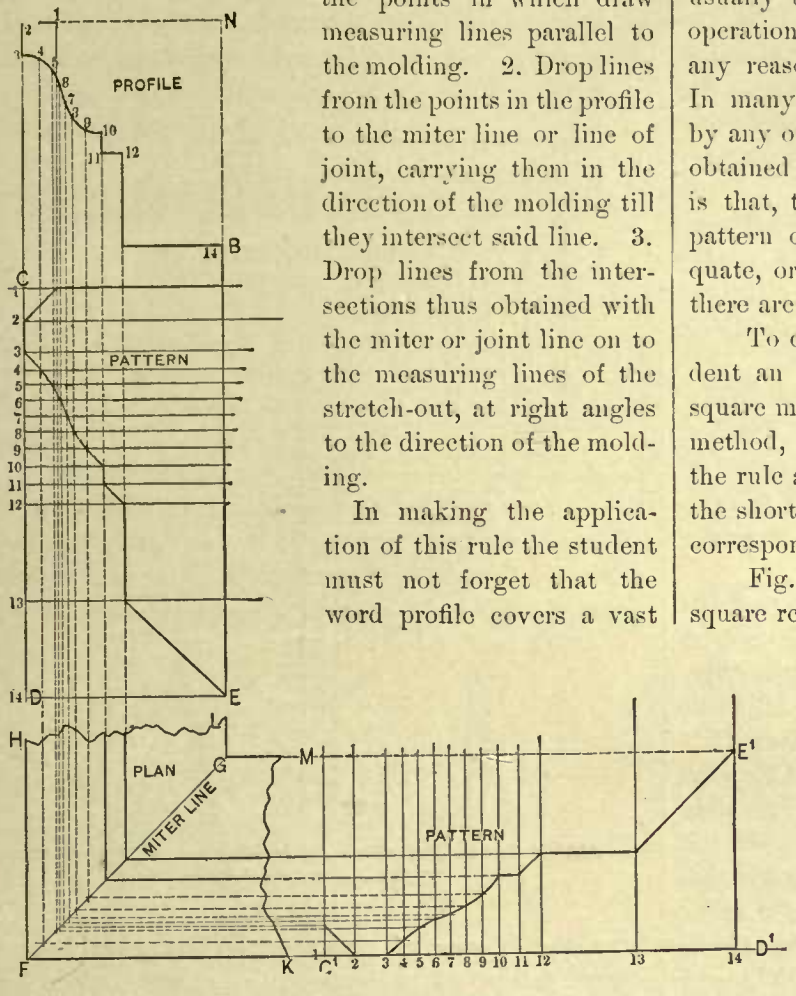


Fig. 241.—Comparison Between the Short or Usual Method of Cutting a Square Miter and the Method Prescribed by the Rule.

The student who gives careful attention to these rules will at once remark that the operation of cutting a common square miter—that is, a miter between the moldings running across two adjacent sides of a square building, for example—does not employ a miter line, and, therefore, appears to be an exception. Yet it has been remarked that a thorough understanding of how a square miter is cut comprehends within itself the science of miter cutting. The square return miter—for such is the distinctive name applied to the kind of square miter in question—is an exception to the general rule only in the sense that it admits of an abbreviated method. The short rule for cutting it is usually the first thing a pattern cutter learns, and the operation is very generally explained to him without any reason being given for the several steps taken. In many cases it would bother him to cut the pattern by any other than the short method, even after he had obtained considerable proficiency in his art. Hence it is that, to all who have any previous knowledge of pattern cutting the rules above set forth seem inadequate, or, to put it otherwise, are a formula to which there are exceptions.

To clear up these doubts in the mind of the student an illustration of the short method of cutting a square miter is here introduced, and afterward the long method, or the plan which is in strict accordance with the rule above given, will be presented, combined with the short method, thus showing the relationship and correspondence between the two.

Fig. 240 shows the usual method of developing a square return miter, being that in which no plan line is employed. The profile A B is divided into any convenient number of spaces, as indicated by the small figures in the engraving. The stretch-out E F is laid off at right angles to the lines of the moldings, and, through the points in it, measuring lines are drawn parallel to the lines of moldings. From the points established in the profile lines are dropped cutting corresponding measuring lines. Then the pattern or miter cut G H is obtained by tracing a line through these points of intersection.

In this operation it will be noticed that the stipulations of the first part of the rule have been fully complied with—that is, the stretch-out line has been drawn at right angles to the lines of the molding, and measuring lines have been drawn parallel to those lines, but it would seem that the second and third parts of the rule as given are not applicable. Apparently no miter line has been employed, but the points have been dropped directly from the profile into the measuring lines.

In order to make this clear Fig. 241 is here introduced in which the proper relation of parts is shown and in which the pattern is developed according to rule, and in which is also shown the short method and how it is derived from the long method.

As the angle of a return miter can only be shown by a plan, the plan becomes the first necessity according to the rule and is shown in the cut by H F K M G L, F G showing the line upon which the two arms of the molding meet—that is, the miter line. The profile A B appears duly in line with one arm of the plan H F G L. This arm, then, is the part of which the pattern is about to be developed; accordingly the stretch-out line is then drawn at right angles to this arm, as shown at C′ D′, and the measuring lines drawn parallel to the arm.

The second part of the rule is now carried out; that is, lines are dropped from the points in the profile A B to the miter line F G and from thence at right angles to F H into the measuring lines, thus obtaining the pattern C′ E′.

In the upper part of this figure another stretch-out, C D, is introduced into which lines have been dropped directly from the points in the profile, thus producing the pattern at C E, making this part of the figure a reduplication of the method employed in the previous figure.

By comparison it will be seen that the two patterns C E and C′ E′ are identical. Since the two arms of the miter are identical and at right angles to each other, the miter line must bisect the angle H F K and be at an angle of 45 degrees to either of the two faces H F and F K. From this it appears at once that the projection of any and all points upon F G from the plan line G L toward H is exactly the same as from the plan line G M toward K and that the relationship between C E and the miter line, and C′ E′ and the miter line, is, therefore, the same. Dropping points from a profile against a line inclined 45 degrees, as F G, and thence on to a stretch-out, gives the same result as dropping them on the stretch-out in the first place. Hence it is that the portion of the operation shown in the lower part of the engraving may be dispensed with. This relationship could never occur were the angle of the miter anything else than a right angle.

Another and perhaps simpler explanation of this is given in connection with Problem 3, in Section 1 of Chapter VI.

A very common mistake made by beginners in attempting to apply the general rule for cutting miters as given, is that of getting the miter line in a wrong position with reference to the profile. For example, instead of drawing a complete plan, as shown by L H F K M in Fig. 241, by which the miter line is located to a certainty, and in connection with which it is a simple matter to correctly place the profile, it is not uncommon to attempt the operation by drawing the miter line only, placing it either above, below or at one side of the profile. The mistake is made by having the line at the side of the profile when it should be either above or below it, and vice versa. Fig. 242 illustrates a case in point. The engraving was made

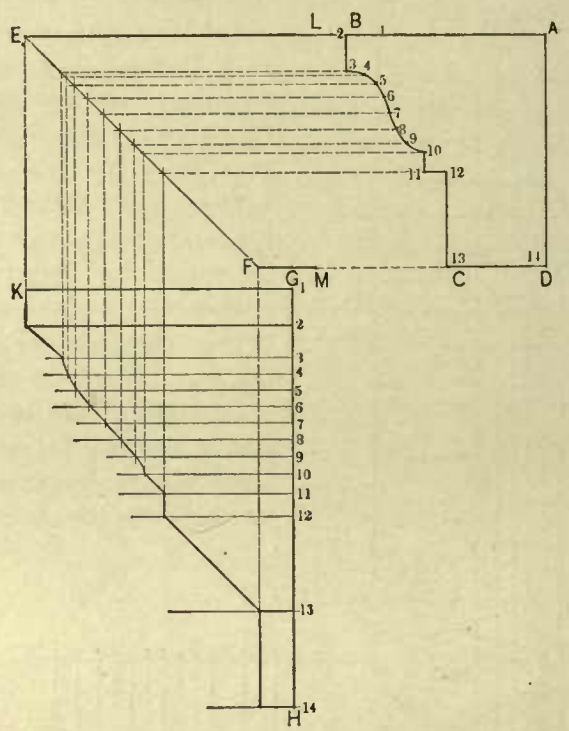


Fig. 242.—A Square Face Miter Produced Where a Square Return Miter was Intended.

from the drawing of a person who attempted to cut a square return miter by the rule, using a miter line only. By placing the miter line E F at the side instead of below the profile, a square face miter—such as would be used in the molding running around a panel or a picture frame—was produced in place of what was desired.

In order to avoid such errors the reader is recommended to a careful perusal of the chapter on Linear Drawing (Chapter III), where the relation existing between plans, elevations and sections or profiles is thoroughly explained. It is better to draw a complete plan, as shown in Fig. 241, thus demonstrating to a cer-

tainty the correct relationship of the parts, than to save a little labor and run the risk of error.

As remarked in the earlier part of this chapter, some labor is often necessary before the *requirements* mentioned above in connection with the rule can be fulfilled. Sometimes a miter line must first be developed, and sometimes the profile of a molding must undergo a change of profile known as *raking*. It is believed that the principles underlying these operations are made sufficiently clear in connection with the problems in which they are involved not to need especial explanation in this connection. Suffice it to say that, in many instances, half the work is done in the getting ready.

Regular Tapering Forms.

(FLARING WORK.)

This subject embraces a large variety of forms of frequent occurrence in sheet metal work, and the development of their surfaces comes under an altogether different set of rules than those applied to parallel forms.

Before entering into the details of these methods it will be best to first define accurately what is here included by the use of the term. These forms include only such solid figures as have for a base the circle or any of the regular polygons, as the square, triangle,

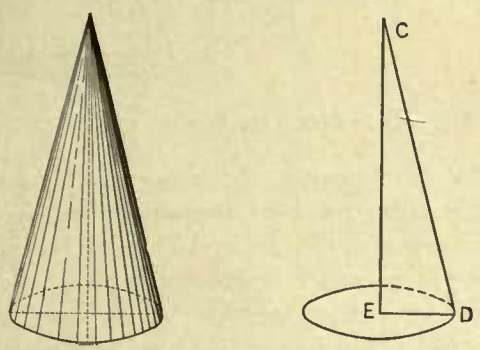


Fig. 243.—A Right Cone Generated by the Revolution of a Right-Angled Triangle about its Perpendicular.

hexagon, etc.; also figures though of unequal sides that can be inscribed within a circle, and all of which terminate in an apex located directly over the center of the base.

While the treatment of these forms has been said to be altogether different from that of parallel forms there are some points of similarity to which the student's attention is called that may serve to fix the methods of work in his memory.

Whereas in parallel forms the distances of the various points in a miter are measured from a straight line drawn through the mold near the miter for that purpose, as C D, Fig. 238, the distances of all points in the surfaces of tapering solids produced by the intersection of some other surface are measured from the apex upon lines radiating therefrom; and

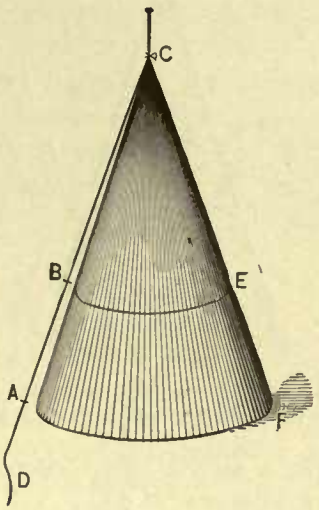


Fig. 244.—A Right Cone with Thread Fastened at the Apex to which are Attached Points Marking the Upper and Lower Bases of a Frustum.

whereas the distance across parallel forms (the stretch-out) is measured upon the profile, the distance across tapering forms is measured upon the perimeter of the base.

Patterns are more frequently required for portions of frustums of these figures than for the complete figures themselves and the methods of obtaining the pattern of coverings of said frustums is simply to develop the surface of the entire cone or pyramid and by a system of measurements take out such parts as are required.

As the apex of a cone is situated in a perpendicular line erected upon the center of its base, it must of necessity be equidistant from all points in the circumference of the base.

In works upon solid geometry the cone is described as a solid generated by the revolution of a right-angle triangle about its vertical side as an axis. This operation is illustrated in Fig. 243, in which it will be seen that the base E D of the triangle C E D is the radius which generates the circle forming the base of the cone, and that the hypothenuse C D in like manner generates its covering or envelope.

If a plane be passed through a cone parallel to the base and at some distance above it, the line which it produces by cutting the surface of the cone must also be a circle, because it, like the base, is perpendicular to the axis. The portion cut away is simply another perfect cone of less dimensions than the first,

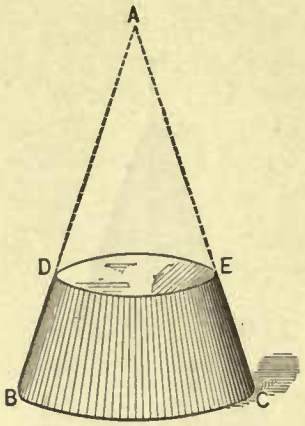


Fig. 245.—Frustum of a Right Cone, the Dotted Lines Showing the Portion of the Cone Removed to Produce the Frustum.

while the portion remaining is called a frustum of a cone. A F C, Fig. 244, is a cone, and B D E C, Fig. 245, is a frustum. The line B E, Fig. 244, shows where the cone is cut to produce the frustum.

If, having a solid cone of any convenient material, as wood, a pin be fastened at the apex C of the same, as shown in Fig. 244, and a piece of thread be tied

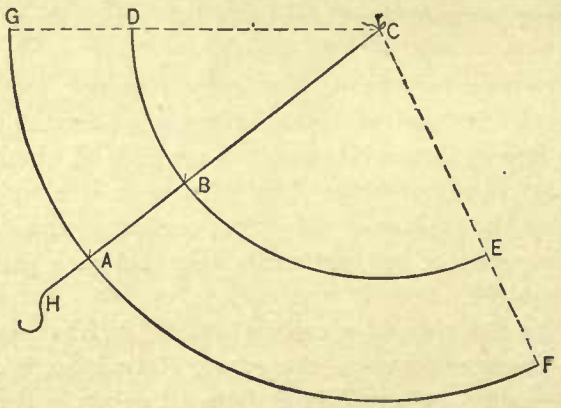


Fig. 246.—Envelope of the Cone and Frustum Described by the Pin and Thread in Fig. 244.

thereto, to which are fastened points B and A, corresponding in distance from the apex to the upper and lower bases of the frustum, and the thread, being drawn straight, be passed around the cone close to its surface, the points upon the thread will follow the lines of the bases of the frustum throughout its course. If then, taking the thread and pin from the cone, and fastening the pin as a center upon a sheet of paper, as shown in Fig. 246, the thread be carried around the pin, keeping it stretched all the time, the track of the points fastened to the thread will describe upon the paper the shape of the envelope of the frustum, as shown by G D E F. By omitting the line produced by the upper of the two points, the envelope of the complete cone G C F will be described. The length of the arc G F described by the point A attached to the thread may be determined by measuring the circumference of the base of the cone by any means most available. The usual method is to take between the points of the dividers a small space and step around the circumference of the circle of the base and set off upon the circle of the pattern the same number of spaces.

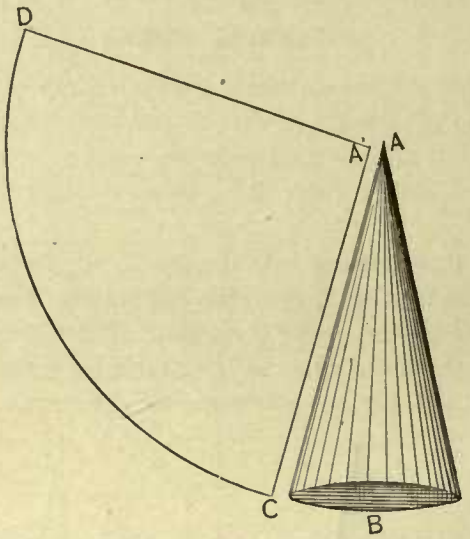


Fig. 247.—Unfolding the Envelope of a Right Cone.

The development of the envelope of a cone may be further illustrated by supposing that, in the case of the wooden model, it be laid upon its side upon a sheet of paper and rolled along until it has made one complete revolution; a point having been previously marked upon the line of its base by which to determine the same. The base B, Fig. 247, thus becomes stretched out as it were, describing the line C D upon the paper, while the apex A, having no circumferference, remains stationary at the point A'. The lines C A' and D A' represent the contact of the side of the cone at the beginning and at the finish of one revolution.

As in the case of dividing the profile in parallel forms, this method is, theoretically, only approximate in accuracy, but the difference is so slight practically that it is not worth considering. Of course, the shorter

the spaces are the greater is the accuracy. This method has, however, another significance which will be pointed out later on, which will help to simplify the solution of all tapering forms.

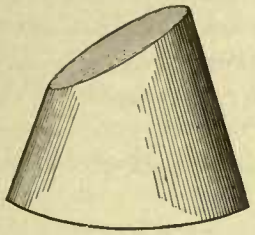


Fig. 248.—A Cone Truncated Obliquely.

If it is required that the cone should be truncated obliquely, as shown in Fig. 248, it will be seen that all the points in the upper line of the frustum are at different distances from the base, or, what amounts to the same thing, from the apex of the original cone, hence some method of measuring these distances must be devised.

To explain the principles here involved more

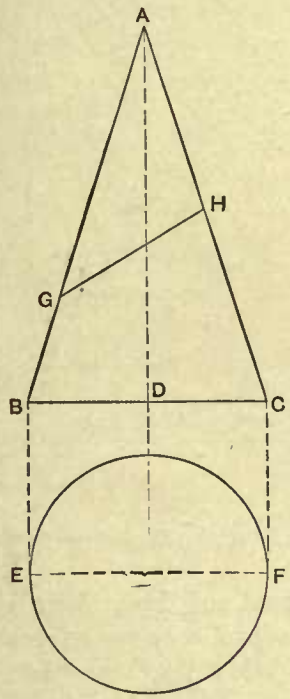


Fig. 249.—Plan and Elevation from which to Construct a Wooden Cone for Purposes of Illustration.

clearly, suppose that a cone be cut from a solid block of wood and of a hight and width to agree with some particular drawing, as, for instance, the one shown in Fig. 249. Divide the circle of the base E F upon the drawing into a convenient number of parts or spaces and mark the same number of points and spaces upon the edge of the base of the wooden cone, and from each of these points draw upon the sides of the wooden cone straight lines running to its apex.

A correct elevation of these lines upon the drawing may be obtained by carrying lines from the divisions or points in the plan of the base vertically till they strike the line of the base B C in the elevation, as shown in Fig. 250, thence to the apex A, cutting the line G H.

Now, if by means of a saw the upper part of the wooden cone be removed, being cut to the required angle as shown by the oblique line G H in the drawing, an opportunity is given, by the lines upon the

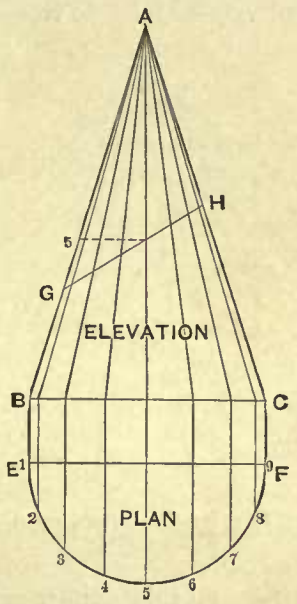


Fig. 250.—Method of Obtaining the Lines upon the Elevation.

part of the cone cut away, of measuring accurately the distance of each point of the curve thus produced from the apex.

Then as all points in the base B C are equidistant from the apex A, to lay out the pattern of this frustum, first describe an arc of a circle whose radius is equal to the length of the side (or slant hight) of the cone A B, Fig. 250. Make this arc in length equal to the circumference of the base B C of the cone by means of the points, as previously described. To avoid confusion number these points 1, 2, 3, etc., from the starting point B, and from each of these points draw lines to the center of the arc, all as shown in Fig. 251.

Now, replacing that portion of the cone which was cut away so as to identify the lines upon its sides

by the numbers at the base, the length of each line from the apex down to the cut can be measured by the dividers and transferred to the lines of the same numbers in the diagram, Fig. 251, as shown between G and H.

All this no doubt is quite simple when the model is at hand upon which to make the measurements. It is quite evident that it will not do to measure the distance upon the drawing, Fig. 250, from the apex A to the points of intersection on the line G H because the sides of the cone having an equal slant of flare all around, the lines upon the drawing do not represent the real distances except in the case of the two outside lines; the slant hight of a cone or any part of a cone being greater than the vertical hight of same part. But as these two outside lines do represent the correct

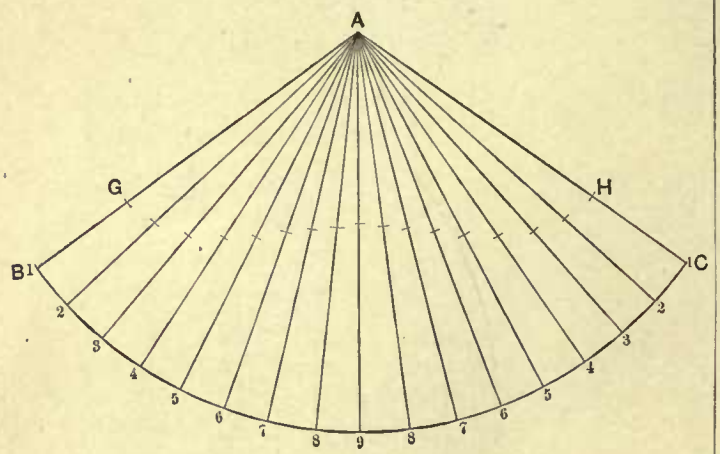


Fig. 251.—Method of Deriving the Pattern of a Frustum from the Wooden Model.

slant of the cone on all sides, either one of them may be taken as a correct line upon which to measure these distances; that is, as a vertical section through the cone upon any or all of the lines drawn upon its sides.

To make it a perfect section upon any one of these lines, say line 5, it is simply required that the position of the point of intersection of line 5 with the line G H be shown, which is done by carrying this point horizontally across till it strikes the side of the cone A B at 5, as illustrated in Fig. 250. The result of repeating this operation upon all the other lines is as though a thread or wire were stretched from the apex down along the side of the cone to the point B in the base and the cone were turned upon its axis, and as each line upon the side passes under the thread, the point where it cuts the intersecting plane G H where marked thereon, thus collecting all the points into one section as it were.

This operation is fully shown in Fig. 252, to which is added the development of the pattern, which is exactly the same as that shown in Fig. 251, the distances of the points between G and H from A being obtained in this case from the points upon the line A B, instead of from the model, as before. The points on A B are transferred to lines of corresponding number in the pattern by means of the compasses, as shown.

Should the frustum of which a pattern is required

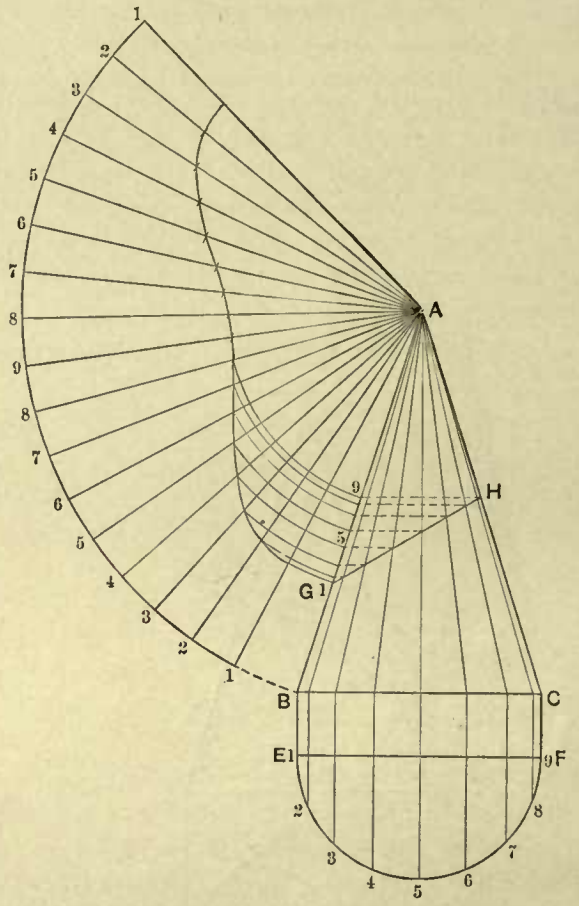


Fig. 252.—Method of Deriving the Pattern from the Drawing.

have both its upper and lower faces oblique to the axis of the cone a level base can be assumed at a convenient distance below the lower face of the frustum from which the circumference can be obtained and then both the upper and lower faces of the frustum can be developed by the method just described.

A right cone having an elliptical base might seem to belong in the same class with regular tapering forms, but as the distance from its apex to the various points in the perimeter of its base is constantly varying, it is therefore placed in the class with irregular forms in

the following section of this chapter, where it will be duly discussed. But as tapering articles of elliptical shape are of frequent occurrence, and as the circle is much easier made use of than the ellipse, such articles are usually designed with approximate ellipses composed of arcs of circles. This method is in many cases especially desirable, as articles so designed have an equal amount of flare or taper on all sides, which would not be the case if they were cut from elliptical cones. It will thus be seen that an article designed in that manner is the envelope of a solid composed of as many portions of frustums of right cones as there were arcs of circles used in drawing its plan.

In Fig. 253 is shown the usual method of drawing the plan and elevation of an elliptical flaring article, the outer curve of the plan A C B D being the shape at M N of the elevation, while the inner curve I G V J is the plan at the top K L. As many centers may be employed in drawing the curves of the plan of such an article as desired, all of which is explained in the chapter on Geometrical Problems (Chap. IV.), Problems 73, 76 and 78. To simplify matters only two sets of centers have been employed in the present drawing, all as indicated by the dotted lines drawn from the various centers and separating the different arcs of circles. Reference to the plan now shows that that portion of the article included between the points E

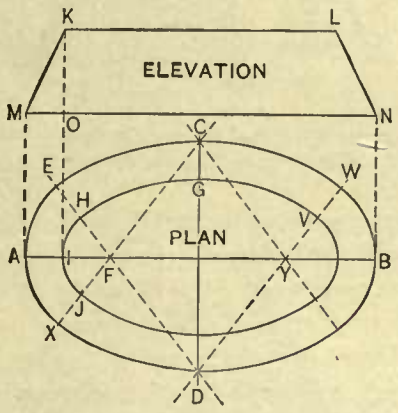


Fig. 253.—Usual Method of Drawing an Elliptical Flaring Article.

C W V G H is a position of the envelope of a cone the radius of whose base is D C and whose apex is located at a point somewhere above D; and likewise that that portion included between the points X A E H I J is part of a cone the radius of whose base is A F and whose apex is somewhere upon a line erected at F. Thus four sectors cut from cones of two different sizes go to make up the entire solid of which the article shown in Fig. 253 is a frustum.

To determine the dimensions, then, of such cones it is necessary to construct a diagram such as that shown in Fig. 254, which is in reality a section upon the line E D of the plan, in which P O and P R are respectively equal to E D and E F of the plan. At points O and R, Fig. 254, erect perpendicular lines O J and R Z indefinitely. Upon O J set off O S equal to the straight hight O K of the frustum, Fig. 253, and

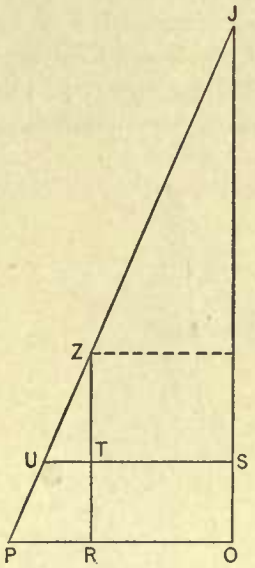


Fig. 254.—Diagram Constructed to Determine the Dimensions of the Cones, Portions of which are Combined to Make up the Article Shown in Fig. 253.

draw S U parallel to O P, which make equal in length to D H. A line drawn through the points P and U will then represent the slant or taper of the frustum, as shown at M K of the elevation, and if continued till it intersects with the perpendiculars from O and P will determine the respective hights of the two cones, as shown by Z and J. Then P J O is the triangle which, if revolved about its vertical side J O, will generate the cone from which so much of the figure as is struck from the centers C and D in Fig. 253 is cut; and P Z R is the triangle which if revolved about its vertical side Z R will generate the cone from which the end pieces of the article are taken. To present this before the reader in a more forcible manner, several pictorial illustrations are here introduced in which the foregoing operations are more clearly shown. In Fig. 255 is shown a view of the plan of the base A C B D of Fig. 253 in perspective, in which the reference letters are the same as at corresponding parts of that plan, and upon which is represented, in its correct position, a sector of the larger cone from which the side portions.

of the frustum are taken. Thus the triangular surfaces F D E and F D W, being sections of the cone through its axis, correspond to the triangle J O P of the diagram, Fig. 254. In Fig. 256 two additional sectors from the smaller cone previously referred to are represented as standing upon the adjacent portions of the plan from which their dimensions were derived. Thus C F and H D, the center lines of their bases, correspond respectively to A F and Y B of the plan, Fig. 253, and the triangles L F G and M H K, being radial sections of the cones, correspond with the triangle Z R P of the diagram. In Fig. 257 is presented the opposite view of the combination seen in Fig. 256,

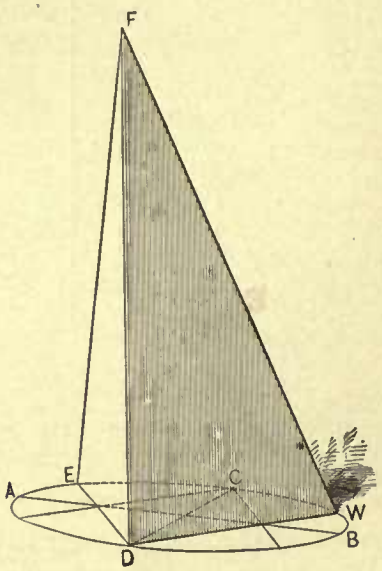


Fig. 255.—Perspective View of the Plan in Fig. 253, with a Sector of the Larger Cone in Position.

showing at C B and D A the joining of their outer surfaces or envelopes.

As previously remarked, two sets of centers only were employed in constructing the plan, Fig. 253, for the sake of simplicity. Had a third set of centers been made use of the arrangement of sectors of cones shown in Figs. 256 and 257 would have been supplemented by a pair of sectors, cut from a cone of intermediate size, which would have been placed on either side of the large sector between it and the smaller ones, all being joined together upon the same general principle as before explained. Reference to Fig. 220 in the chapter on Geometrical Problems shows at J L P, P S W and W U V what the relative position of their bases would be. If it be desired to complete the solid, which has been begun in Fig. 256, it will first be necessary to cut away that portion of the middle sector which stands over the space F H B, Fig. 256. Such a cut might be begun upon the line F H, and passing vertically through the points L and M would finish through the curved surface of the further or curved side of the sector. The cut thus made between the points L and M is shown at D C in the other view, Fig. 257, and is by virtue of the conditions a hyperbola. (See Def. 113, Chap. I.) The piece necessary to complete the solid would then be a duplicate of the shape remaining after making the above described cut, the outer surface of which is shown by A B C D of Fig. 257. The complete solid would then have the appearance shown in Fig. 258.

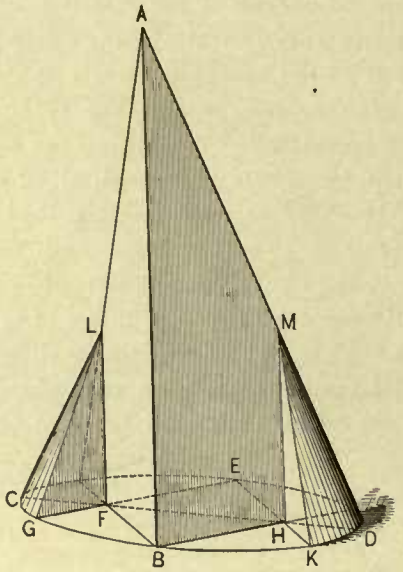


Fig. 256.—The Same Plan Showing Two Sectors of the Smaller Cone in Position Joining the Larger One.

By thus resolving the solid from which the ordinary elliptical flaring article is cut into its component elements the process of developing its pattern may be more readily understood. This process may now be easily explained by returning to the string and pin method which was made use of in connection with the simple cone in the earlier part of this section.

In Fig. 257 is shown a line some distance above the base representing the top of the frustum shown by K L in the original elevation, Fig. 253. It also shows a pin fastened at the apex of the middle conical sector to which is attached a thread carrying points G and H representing the upper and lower surfaces of the frustum. Now, if the string be drawn tight and passed along the side of the larger sector of the cone from A to B the points will follow the upper and lower bases of the frustum. When the point B is

reached, if the finger be placed upon the thread at the apex of the lesser cone, shown at C, and the progress of the thread be continued, the points will still follow the lines of the bases of the frustum. If the pin and

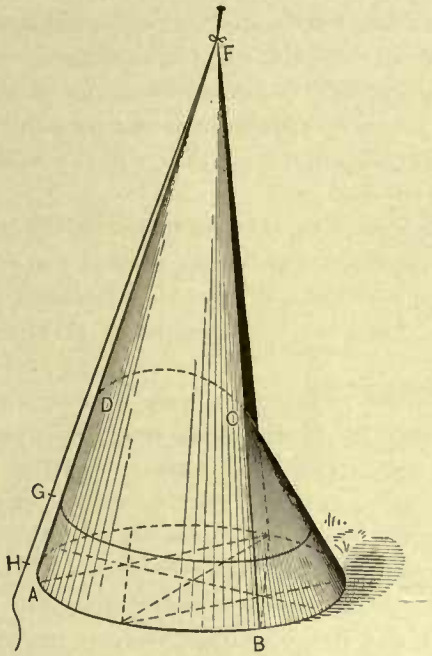


Fig. 257.—Opposite View of Parts Shown in Fig. 256, with String Attached to a Pin at the Apex of the Larger Sector.

thread be taken from the cone and transferred to a sheet of paper, as shown in Fig. 259, the pin A being used as a center and the thread as a radius, the points will describe the envelope of the frustum. First, the radius is used full length, as shown by A L K, and ares L M and K H are drawn in length respectively

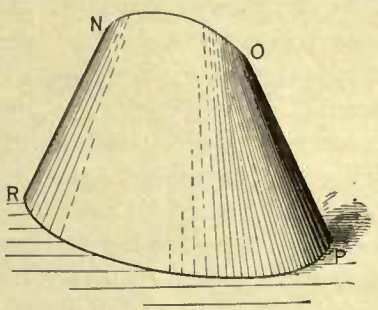


Fig. 258.—The Completed Solid of which the Ordinary Elliptical Flaring Article is a Part.

equal to their representatives H G V and E C W of the original plan, Fig. 253. Then a second pin is put through the string, as shown at B, thus reducing the radius to the length of the side of the lesser cone, and ares are struck in continuation of those first described, making the length of the additional ares equal to those of their corresponding ares H I J and E A X of the original plan.

As the lengths of the sides of the larger and

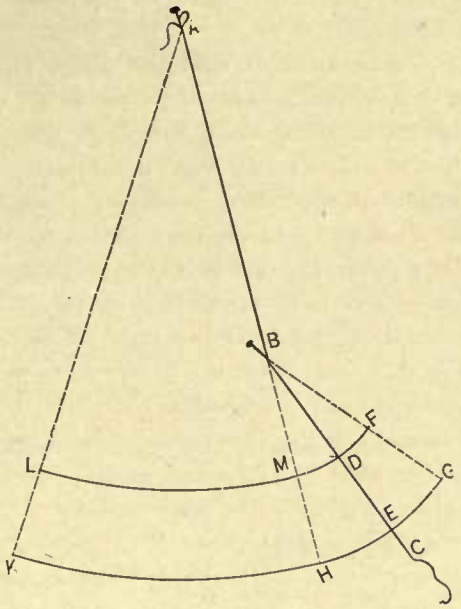


Fig. 259.—The Pin and Thread taken from Fig. 257 and Used in Describing the Envelope.

smaller cones above made use of are by construction equal to J P and Z P, the hypothenuses of the triangles, Fig. 254, by whose revolution they were generated, those distances may therefore be taken at once from that diagram by means of the compasses and used as shown in Fig. 259.

Reference has been made above to the difference between the circumference of the circle of the base obtained by means of the points and spaces (which method becomes a necessity to the pattern cutter) and

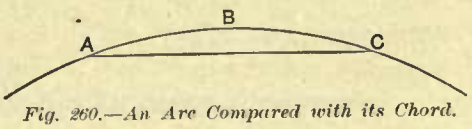


Fig. 260.—An Arc Compared with its Chord.

the real circumference. An explanation of this difference will lead to the next class of regular tapering figures—viz. : pyramids.

In the accompanying diagram, Fig. 260, A B C represents the arc of a circle of which the straight line A C is the chord, being the shortest distance between the two points A and C. Therefore, when dividing a circle by means of points for purposes of measurement, the pattern cutter is in reality using a number of chords instead of the ares which they subtend.

In the practice of obtaining the circumference or stretch-out of a circle the space assumed as the unit of measure should be so small that there is no perceptible curve between the points and, of course, no practical difference between the length of the chord and the length of the arc.

It will thus be seen that the circle representing the base of a cone has in reality become in the hands of the pattern cutter a many sided polygon and that the cone is to him a many sided pyramid. As one of the conditions in describing a regular polygon is that its angles shall all lie in the same circle, so the angles or hips of a pyramid must lie in the surface of the cone whose base circumscribes the base of the pyramid and whose apex coincides with the apex of the pyramid. Viewed in this light then, the lines which were drawn upon the outside of the wooden cone for the purpose of measurement in the illustration used above become the angles or hips of a pyramid and may be used for that purpose in exactly the same manner.

In developing the pattern of a frustum of a cone the line connecting the points between G and H, Fig. 251, is supposed, of course, to be a curved line, while in the case of a pyramid (the points or angles of the pyramid being further apart and the sides of a pyramid being flat instead of curved) the lines of the pattern connecting the points would be straight from point to point.

Irregular Forms.

(TRIANGULATION.)

In some classes of sheet metal work certain forms arise for which patterns are required, but which cannot be classified under either of the two previous subdivisions. Their surfaces do not seem to be generated by any regular method. They are so formed that although perfectly straight lines can be drawn upon them (that is, lines running parallel with the form), such straight lines when drawn would not be parallel with each other; neither would they slant toward each other with any degree of regularity.

While in the systems described in the two previous portions of this chapter distances between lines running with the form measured at one end of an article govern those at the other end, in the forms considered in this department these distances are continually varying and bear no such relation to each other. Thus in parallel forms (moldings) the distance between any two lines running with the form is the same at both ends of the article, while in conical shapes all lines running with the form tend toward a common center or vertex, so that the distances between such lines at one end of the article (provided it does not reach to the vertex) bear a regular proportion to the distances between them at the other end. Hence, in the development of the pattern of an irregular form it becomes necessary to drop all previously described systems and simply proceed to measure up its surfaces, portion by portion, adding one portion to another till the entire surface has been covered.

To accomplish this end one of the most simple of all geometrical problems is made use of, to which the reader is referred (Chap. IV., Problem 36)—viz.: *To construct a triangle, the lengths of the three sides being given.*

As from any three given dimensions only one triangle can be constructed, this furnishes a correct means of measurement; and the solution of this problem in connection with a regular order and method of obtaining the lengths of the sides of the necessary triangles constitutes the entire system. To carry out this system it simply becomes necessary to divide the surface of any irregular object into triangles, ascertain the lengths of their sides from the drawing, and reproduce them in regular order in the pattern, and hence the term TRIANGULATION is most fittingly applied to this method of development of surfaces.

In all articles whose sides lie in a vertical plane, distances can be measured in any direction across their sides upon an elevation of the article, but when the sides become rounded and slanting the length of a line running parallel with the form cannot be measured either upon the elevation or the plan. The elevation gives the distance from one end of the line to the other vertically or as it appears to slant to the right or left, but the distance of one end of the line forward or back of the other can only be obtained from the plan which while supplying this dimension does not give the hight. Consequently the true length of any straight line lying in the surface of any irregular form can only be ascertained by the construction of a right-angle triangle whose base is equal to the horizontal distance between the required points, and whose altitude is equal to the vertical distance of one point above the other, the hypothenuse giving the true distance between the points, or, in other words, the required length of the line.

For illustration, Fig. 261 shows an article which may be called a transition piece, the base of which,

A B C D of the plan, is a perfect circle lying in a horizontal plane, E H of the elevation. Its upper surface, however, N O P Q of the plan, is elliptical in shape and besides being placed at one side of the center is also in an inclined position, as shown by F G of the elevation. To the right of this plan is another drawing of the same, A′ B′ C′ D′, turned one-quarter around from which, and the elevation, is projected another view, J′ K′ L M, which may be called the perimeter at the top. As F G, the distance across the top, is greater than N P (its apparent width in the plan), the curve N O P Q evidently does not give the correct distance around the top, and therefore a correct view of the top must be obtained. The method of accomplishing this does not differ from many similar operations described in connection with parallel forms and is clearly shown in the drawing. Considering N O P Q as a correct plan or horizontal projection of

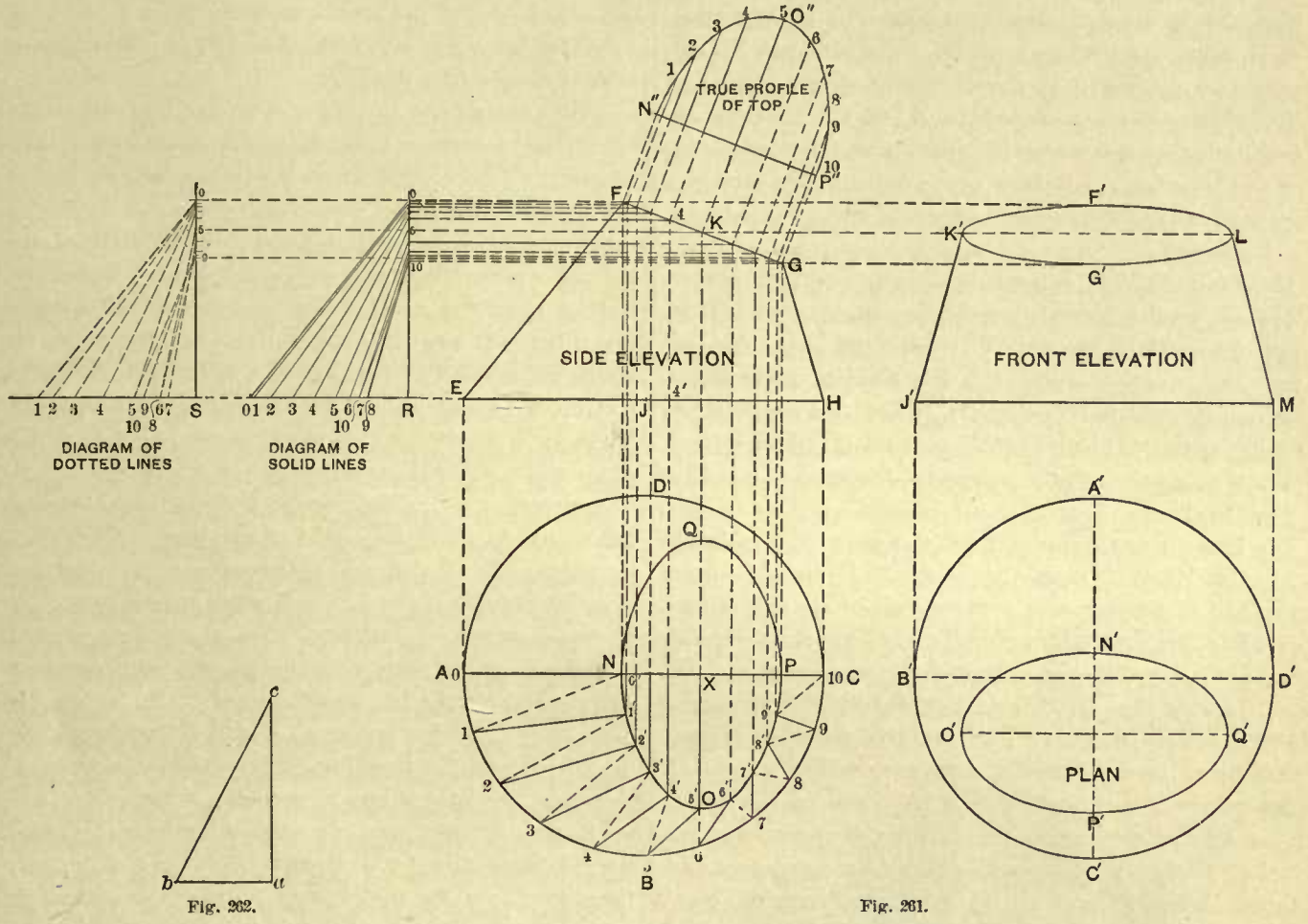


Fig. 262. Fig. 261.

Plans, Elevations, etc., of an Irregular Shaped Article, Illustrating the Principles of Triangulation.

front and which will assist in obtaining a more perfect conception of the shape of the article. A comparison of the three views shows that the slant of the sides is different at every point, and that the only dimensions of the article which can be measured directly upon the drawing are the circumference of the base and the slant hight, as given at E F, H G and L M.

Before a pattern of its side can be developed it will be necessary to ascertain its width (or distance from base to top) at frequent intervals and also its the top, one-quarter of it, as O N, may be divided by any convenient number of points and their distances from N P set off upon the parallel lines drawn from N″ P″, thus obtaining O″ N″, one-quarter of the correct curve. It is more likely, however, that the correct shape of the top N″ O″ P″ would be given, from which it would be necessary to obtain its correct appearance in the plan, which would be accomplished by drawing the normal curve in its correct relation to the line F G, as shown by N″ O″ P″, when the raking

process could be reversed, thereby developing the curve O N P one-half of the plan of top.

Preparatory to obtaining the varying width of the pattern of the side, a number of points must be fixed upon in the curves of both top and bottom from which to take the measurements. As one-quarter of the top is already divided into spaces, another quarter, O P, may be divided into the same number of spaces (also dividing O″ P″ into the same space as O″ N″). If N″ O″ P″ is the normal curve of the top it would very naturally be divided into equal spaces by the dividers, as is usual in such cases, while the spacing in N O P would be the result of the operation of raking. It is advisable to have the spaces in N″ O″ P″ all equal to each other, as it is from this curve that the stretch-out of the top of the pattern is to be derived, the convenience of which will become apparent when the pattern is developed.

The quarter O P is used in connection with the quarter O N, because these two combined constitute a half of the top curve lying on one side of the line A C of the plan which divides the article into symmetrical halves, it being only necessary, when the shape of an article permits, to obtain the pattern of one-half and then to duplicate by any convenient means to obtain the other half.

The corresponding half of the plan of the base, therefore, A B C, must also be divided into the same number of equal spaces as were used at the top, all as shown in the drawing, and both sets of points should be numbered alike, beginning at the same side.

Having thus fixed the points from which measurements across the pattern of the side are to be taken, next draw lines across the plan connecting points of like number, as shown by the full lines in the plan. This divides the entire side of the article into a number of four-sided figures; but as it is necessary, as shown above, to have it divided into triangles, each four-sided figure may now be redivided by a line drawn through its opposite angles, thus cutting it into two triangles. In other words, each point in the base should be connected with a point of the next lower number (or higher, according to circumstances) in the curve of the top, and these lines should be dotted instead of full lines for the sake of distinction and to avoid confusion in subsequent parts of the work. Thus 1 of the base is connected by a dotted line with 0′ of the top, 2 of the base with 1′ of the top, etc.

In respect to which is the best way to run the dotted lines, common sense will be the best guide. Thus, in the space bounded by the lines 4 4′ and 5 5′, it is plainly to be seen that there would be greater advantage and less liability of error in connecting 5 of the bottom curve with 4′ of the top than in crossing the line from 4 of the bottom to 5′ of the top, for the reason that in the former case the triangles produced would be less scalene or acute.

The next step is to devise a means of determining the true lengths which these lines represent or, in other words, their real length as they could be measured if a full size model of the article were cut from a block of wood or clay upon which these lines had been marked, as shown upon the drawing.

The lines upon the plan, of course, only show the horizontal distances between the points which they connect. The vertical hight above the base of any of the points in the upper curve can easily be found by measuring from its position upon the line F G of the elevation perpendicularly to the base E H. Therefore, having both the vertical and the horizontal distance given between any two points, it is only necessary to construct with these dimensions a right angle triangle, and the hypothenuse will give their true distance apart. Thus in Fig. 262 *a b* is equal to the line 4 4′ of the plan, while *a c* is made equal to 4 4′ of the elevation. Consequently *c b* represents the true distance between the points 4′ of the top and 4 of the base. Therefore, to obtain all of these hypothenuses in the simplest possible manner, it will be necessary to construct one or two diagrams of triangles. To avoid confusion it is better to make two; one for obtaining the distances represented by the full or solid lines drawn across the plan and the other for those of the dotted lines. To do this extend the base line E H of the elevation, as shown at the left, at any convenient points, in which, as R and S, erect two perpendicular lines. Project lines horizontally from all the points in F G, cutting these two lines as shown, and number the points of intersection. (Some of the figures are omitted in the drawing for lack of space.) From R set off on the base line distances equal to the lengths of the solid lines of the plan 1 1′, 2 2′, 3 3′, etc., numbering the points 1, 2, 3, etc., as shown, and connect points of similar number upon the base with those upon the perpendicular. From S set off on the base line distances equal to the lengths of the dotted lines of the plan 1 0′, 2 1′, 3 2′, etc., and number them to correspond with figure upon the line of the base A B C. Thus make 1 S equal to 1 0′ of the plan, 2 S equal to 2 1′ of the plan, 3 S equal to 3 2′, etc., and connect

each point in the base with the point of next lower number upon the perpendicular by a dotted line, as 1 on the base with 0 on the perpendicular, 2 with 1, 3 with 2, etc. The entire surface of the piece for which

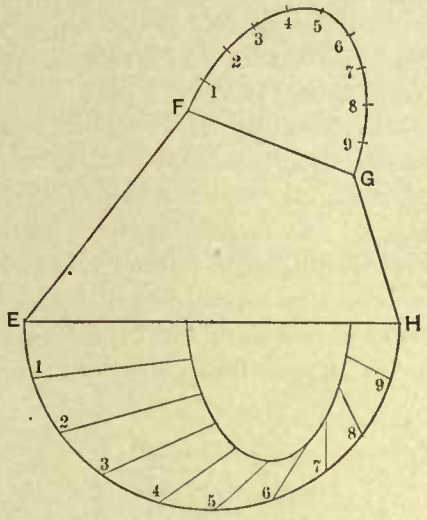


Fig. 263.—Top, Back and Bottom for a Model of One-half the Article Shown in Fig. 261.

a pattern is required has thus been cut up into two sets of triangles, one set having the spaces upon the base line A B C, which are all equal, for their bases, and the other set having the spaces in the curve N″ O″ P″ of the top, also equal to each other, as their bases, and each separate triangle having one solid line and one dotted line as its sides.

In all of this work the student's powers of mental conception are called into play. The shape of the surface, which is yet to be developed, has been spoken of as if it really existed—in fact, it must exist in the mind or imagination of the operator in order to make him intelligent as to what he is doing. If this fails him, he can resort to a model which can easily be constructed (full size or to scale, according to convenience) as follows: Describe upon a piece of cardboard or metal the shape E F G H, Fig. 261, to which add on its lower side, E H, one-half of the plan of the bottom, A B C, with the curve N O P and the solid lines connecting it with the outside curve traced thereon. Also add on its upper side, F G, one-half the shape of top, N″ O″ P″, marking the points 1, 2, 3, etc., upon its edge. Now cut out the entire shape in one piece, as shown in Fig. 263, and bend the same at right angles, on the lines F G and E H. Small triangles of the shape and size of each of the triangles shown in the diagram of solid lines, Fig. 261, as 0 0 R, 1 1 R, 2 2 R, etc., can now be cut out and placed upon the portion representing the bottom, each with its base upon the solid line which it represents, at the same bringing the apex of each to the corresponding number on the top. These can be fastened in place by bits of sealing wax, or if cut from metal the whole can be soldered together.

The hypothenuses of the various triangles will thus represent the true distances across the pattern upon the solid lines of the plan, while the distances upon the dotted lines can be represented by pieces of thread or wire, placed so that each will reach from the point at the base of one of the triangles to the point at the top of the one next it. If constructed of metal two or three triangles will suffice to give the model sufficient rigidity, and the remaining points can be connected by pieces of wire, using a different kind of wire to represent the distances on the dotted lines.

In Fig. 264, is shown a pictorial representation of a model constructed, as above described, from the drawings shown in Fig. 261. In the illustration the triangles 2, 5 and 8 only are shown in position, their hypothenuses connecting points of similar number in the upper and lower bases. The other points are represented as being connected by wires or threads representing both the solid and the dotted hypothenuses in the diagrams of triangles in Fig. 261. Such a model if constructed will give a general idea of the shape of the entire covering, and at the same time of the small pieces, or triangles, of which the covering is composed, with all the dimensions of each. If all of the spaces formed upon this skeleton surface could be filled in

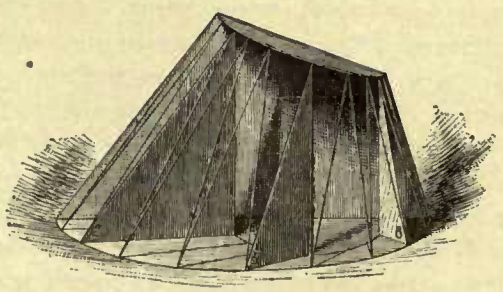


Fig. 264.—Perspective View of Cardboard Model of One-half the Article Shown in Fig. 261.

with pieces of cardboard or metal just the size of each and the whole removed together and flattened out (each piece being fastened to its neighbor at the sides), it would constitute the required pattern, the same as will be subsequently obtained by measurements taken from the drawing, and as shown in Fig. 265.

Having by means of the diagrams of triangles in Fig. 261 obtained the lengths of all the sides it is now only necessary to construct successively each triangle in the manner described in Chapter IV, Problem 36, remembering that the last long side of each triangle used is also the first long side of the next one to be constructed. Therefore, at any convenient place draw any straight line, A N of Fig. 265, which make equal to the real distance from A to N, Fig. 261, which has been found to be the distance 0 0 of the diagram of solid lines. To conduct this operation with the greatest economy and ease it is necessary to have two pairs of dividers, which shall remain set, one to the spaces upon the plan of the base A B C, and the other to the spaces upon N″ O″ P″, and a third pair for use in taking varying measurements. From A of Fig. 265 as a center, with a radius equal to 0 1 of the plan, Fig. 261, describe a small arc, and from N as a center, with a radius equal to the true distance from N to 1 of the plan, which has been found to be 0 1 of the diagram of dotted lines, describe another arc, cutting the first one as shown at the point 1, Fig. 265. The triangle thus constructed represents the true dimensions of one indicated by the same figures of the plan. Next from N of the pattern as a center, with a radius equal to N″ 1 of true profile of top, Fig. 261, describe a small arc, which cut with one struck from point 1 of pattern as a center, with a radius equal to 1 1 of the diagram of solid lines, thus locating point 1′ of pattern. This triangle is, in turn, succeeded by another whose sides are next in numerical order, that is 1 2 of the base and 1 2 of the diagram of dotted lines. Thus the operation is continued, always letting the spaces of the circumference of base succeed one another at one side of the pattern, and the spaces upon the true profile of top succeed one another at the other side of the pattern, until all the triangles have been laid out as shown by A N P C, Fig. 265, which will complete one-half the entire pattern.

It is not necessary to draw all of the dotted or solid lines across the pattern, as the points where the small ares intersect are all that are really needed in obtaining the outlines of the pattern, but it is often advisable to draw them as well as to number each new point as obtained, in order to avoid confusion and insure the order of succession.

In dividing the curves of top and bottom into spaces, such a number of points should be taken as will insure the greatest accuracy, as in the case of dividing a profile. Thus too few would give too short a stretch-out, while if the spaces were too small error in transferring their lengths might result, which would be increased as many times as there were spaces.

Under the head of transition pieces may be included a large number of forms having various shaped polygonal or curved figures as their upper and lower surfaces, placed at various angles to each other, sometimes centrally located as they appear upon the plan and sometimes otherwise. It often happens that one surface or termination is entirely outside the other in that view, forming an offset between pipes of differing sizes and shapes. Sometimes such an offset takes a curved form, constituting a curved elbow of varying section throughout its length, in which case it consists of a number of pieces, each with a different shape at either end. With such forms may be classed the ship

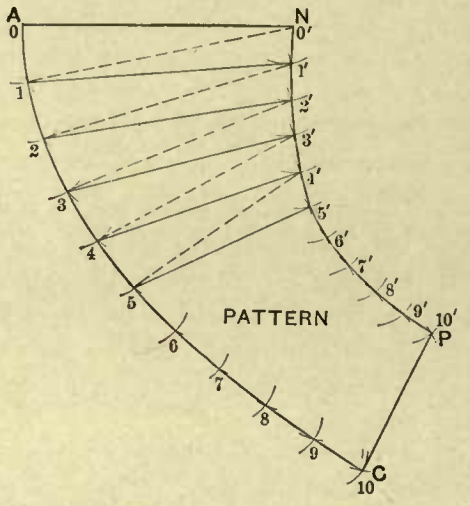


Fig. 265.—One-half Pattern of Side of Article Shown in Fig. 261.

ventilator, whose lower end is usually round and horizontal and whose upper end is enlarged and elliptical and stands in a vertical position, the whole being composed of five or six pieces. In such cases, when the shape and position of the two terminating surfaces only are given, it becomes necessary to assume or draw as many intermediate surfaces as there are joints required, each of such a shape that the whole series will form a suitable transition between two extreme shapes. It may be remarked, that what have been spoken of here as "surfaces" do not necessarily mean surfaces of metal forming solid ends to the pieces described, but simply outlines upon paper to work to, as more often the "surface" is really an opening.

Still another class of forms demanding treatment by triangulation result from the construction of arches

cut through curved walls, as when an arch of either round or elliptical form, as a door or window head, is placed in a circular wall in such a manner that its sides or jambs are radial, or tend toward the center of the curve of the wall. It will be seen that the soffit of such an arch is similar in shape to the sides of a transition piece, having what might be called its upper and lower surfaces curved and placed vertically. In such cases it is best to consider the horizontal plane passing through the springing line of the arch as the base from which to measure the hights of all points assumed in the outer and inner curves.

It is believed that a sufficient number of this gen-

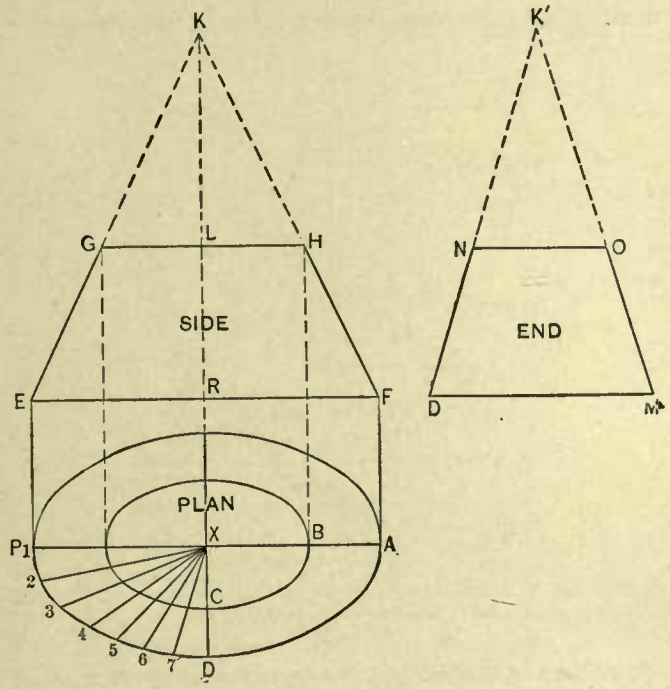


Fig. 266.—Elevations and Plan of an Elliptical Cone.

eral class of problems will be found in the third section of the chapter on Pattern Problems to enable the careful student to apply the principles here explained to any new forms that might present themselves for his consideration, remembering that any form may be so turned as to bring any desired side into a horizontal position to be used as a base, or that an upper horizontal surface can be used as a base as well as a lower.

The operations of triangulation undoubtedly require more care for the sake of accuracy than those of any other method of pattern cutting, for the reason that there is no opportunity of stepping off a continuous stretchout, at once, upon any line, either straight or curved. It is therefore not to be recommended if the subject in hand admits of treatment by any regular method without too much subdivision. Triangulation is not introduced as an alternate method, but as a last resort, when nothing else will do.

Besides the various forms of transition pieces, another class of forms is to be treated under this head, which might almost be considered as regular tapering articles. They include shapes, or frustums cut from shapes, which terminate in an apex, but whose bases cannot be inscribed in a circle, as irregular polygons, figures composed of irregular curves as well as the perfect ellipse. A solid whose base is a perfect ellipse and whose apex is located directly over the center of its base (in other words, an elliptical cone) is perhaps the best typical representative of this class of figures. If the base of such a cone be divided into quarters by its major and minor axes, it will be seen at once that all of the points in the perimeter of any one quarter will be at different distances from the apex of the cone, because they are at different distances from the center of base or the intersection of the two axes. This is clearly shown in Fig. 266, in which are shown the two elevations and the plan of an elliptical cone. The side elevation shows K E to be the distance of the apex from the point P in the plan of the base, while the end elevation shows K′ D to be the distance of the apex from the point D of the base, or the true distance represented by X D of the plan.

If one-quarter of the plan of the base, as D P, be divided into any convenient number of equal spaces and lines be drawn to the center X, as shown, each line will represent the horizontal distance of a point in the perimeter from the apex; and if a section of the cone be constructed upon any one of these lines, as, for instance, line 4 X, or, in other words, if a right angle triangle be drawn, of which 4 X is the base and R K the altitude, the hypothenuse will be the true distance of the point 4 from the apex. Therefore, to ascertain the distances from the apex to the various points in the circumference of the base construct a simple diagram of triangles, as shown in Fig. 267, viz.: Erect any perpendicular line, as X M, equal in hight to R K of the elevation; from X, on a horizontal line X P, as a base, set off the various distances of the plan, X 1, X 2, X 3, etc., numbering each point, and from each point draw a line to M. These hypothenuses will then represent the distances of the various points in the perimeter of the base from the apex of the cone; or, in other words, the sides of a number of triangles forming the envelope of the cone, the bases of which triangles

will be the spaces 1 2, 2 3, etc., upon the plan. As all of these triangles terminate at a common apex or center, instead of laying out each one separately to form a pattern, as in the case of an article of the type shown in Fig. 261, the simplest method is as follows:

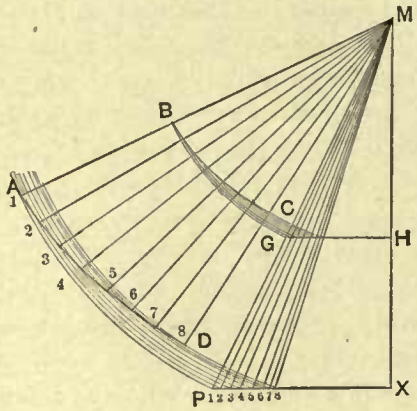


Fig. 267.—Diagram of Sections on the Radial Lines of the Plan in Fig. 266, to which is Added the Pattern of One-quarter of the Envelope.

From M, of Fig. 267, as a center, with radii corresponding to the distances from M to points on P X, as M 1, M 2, M 3, etc., describe arcs indefinitely, as shown to the left; then taking the space used in stepping off the plan between the points of the dividers, place one foot upon the arc drawn from point 8, as at D, and swing the other foot around till it cuts the arc drawn from point 7; from this intersection as a center swing it around again, cutting the arc from 6; or in other words, step from one arc to the next till one-quarter of the circumference has been completed.

As the spaces in the base are equal, it is clearly a matter of convenience whether this last operation is

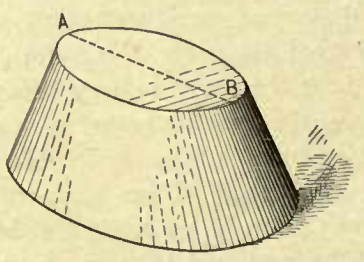


Fig. 268.—Frustum of an Elliptical Cone.

begun upon arc 8, stepping first to arc 7, then to arc 6, etc., or whether it is begun upon arc 1, stepping first to arc 2, then to 3, etc., till complete. A line traced through these points, as A D, will give the cut at the base of the envelope, and A D M will be the envelope of one-quarter of the cone.

In Fig. 268 is shown a perspective view of the frustum of the cone shown in Fig. 266, the upper surface A B being shown in Fig. 266 by the lines G H and N O. If the envelope of such a frustum is desired the cut which its upper surface would make through the envelope of the entire cone could be obtained in exactly the same manner as that of its lower base, because the upper surface of the frustum is in reality the base of the cone, which remains above after the lower part has been cut away. But as part of the operation has already been performed in obtaining the cut at the base, it is most easily accomplished as follows: First draw radial lines from the point M of the diagram of

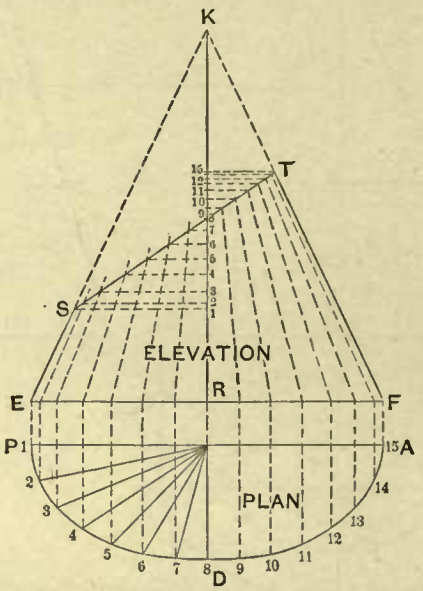


Fig. 269.—Elevation of the Frustum of an Elliptical Cone.

triangles, Fig. 267, to each of the points previously obtained in the cut at the bottom of the envelope, between A and D; also draw a horizontal line at a hight above the base X P equal to R L, Fig. 266, cutting the hypothenuses M 1, M 2, etc., as shown by G H. Now place one foot of the dividers at the point M, and bringing the other foot successively to the various points of intersection of the line G H with the various hypothenuses, describe arcs cutting the radial lines in the envelope of corresponding number. A line traced through the points of intersection, as B C, will give the cut at the top of the envelope of the frustum, of which A D is the bottom cut.

If the cut at the top of the frustum is to be oblique instead of horizontal, a means must be devised for

measuring the distance from the apex at which the oblique plane cuts each of the hypothenuses, or in other words, each of the lines drawn from the apex of the cone to the various points in its base. In Fig. 269, E S T F is the elevation of an oblique frustum of an elliptical cone, whose apex is at K, and whose base is the same and has been divided in the same manner as that shown in Fig. 266.

Erect lines from each of the points in the curve of one-half the plan P D A to the base line E F of the elevation, thence carry them toward the apex K, cutting the line S T; the vertical hight of the points upon S T can then most easily be measured by carrying them horizontally, cutting the center line R K of the cone, where to avoid confusion they should be numbered to

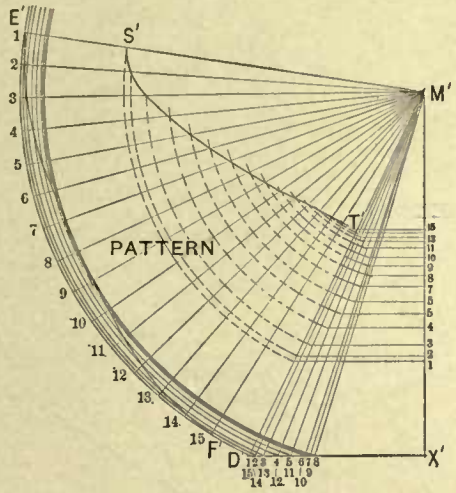


Fig. 270.—Diagram of Sections on the Radial Lines of the Plan in Fig. 269, with the Pattern of One-half the Envelope.

correspond with the points of the plan from which each was derived. These points may now be transferred in a body by any convenient means to the vertical line X′ M′ of the diagram of triangles, Fig. 270, seeing that each point is placed at the same distance from M′ that it is from the point K of Fig. 269. A horizontal line from any one of the points on the line X′ M′ extended to the hypothenuse of corresponding number will then give the correct distance of that point from the apex of the cone. The diagram M′ X′ D′ is a duplicate of M X P of Fig. 267, and the lower outline of the envelope is the same as that shown in Fig. 267. It will be noted, however, that half the stretchout of the base is necessary in this case to give all the essentials of the pattern of the envelope, while one-quarter was sufficient for the previous operations. When all the points in the upper line of the frustum have been obtained in the diagram they may be transferred to the various radial lines in the envelope, from M′ as a center, by the use of the compasses as before, all as shown in the drawing.

If the apex of the cone were not located directly over the crossing of the two axes of the ellipse—that is, if the cone were scalene or oblique instead of right—the method of obtaining its envelope, or parts of the same, would not differ from the foregoing. Lines drawn from the points of division in the circumference of the base to the point representing the position of the apex in the plan will be the horizontal distances used in constructing a diagram of triangles, which distances can be used in connection with the vertical hight of the cone, as before, in obtaining the various hypothenuses. If the apex of a scalene cone be located over the line of either axis of the ellipse, either within the perimeter of the base or upon one of those lines continued outside the base, one-half the pattern of the entire envelope will have to be obtained at one operation; but if the apex is not located upon either of those lines in the plan, then the entire envelope must be obtained at one operation, as no two quarters or halves of the cone will be exactly alike.

The method of obtaining the envelope of any scalene cone, even though its base be a perfect circle, is governed by the same principles as those employed in the above demonstrations.

It will be well to remember that any horizontal section of a scalene cone is the same shape as its base, which fact can be used to advantage in determining the best method to be employed in obtaining the envelope of any irregular flaring surface that may be presented. If, for instance, the plan of any article, whose upper and lower surfaces are horizontal, shows each to consist of two circles or parts of circles of different diameters not concentric, it is evident that the portion of the envelope indicated by the circles of the plan is part of the envelope of a scalene cone. An illustration of this is given in Fig. 271, which shows a portion of an article having rounded corners and flaring sides and ends, but with more flare at the end than at the side. The plan shows the curve of the bottom corner A B to be a quarter circle with its center at X, and that of the top C D to be a quarter circle with its center at Y. The rounded corner A B D C is then a portion of the envelope of a frustrum of a scalene cone, and the method of finding the dimensions of the complete cone is quite simple and is as follows: First draw a line, Z N, through the centers of the two circles in the plan,

at right angles to which project an oblique elevation, as shown below, making the distance between the two lines E F and G H equal to the hight of the article. Lines from X and M of the plan of the bottom fall upon G H, locating the points X′ and H, while lines from Y and N of the top locate the points Y′ and F in the upper line of the oblique elevation. A line drawn through Y′ and X′, the centers of the circles, will then represent the axis of the cone in elevation, which can be continued to meet a line drawn through the points F and H, representing the side of the cone, thus locating the apex Z′ of the scalene cone. The point Z′ can then be carried back to the plan, as shown at Z, thus locating the apex in that view. As the line N Z represents the horizontal distance between the point F and the apex Z′ of the cone, so lines drawn from Z to any number of points assumed in the curve of the base C D will give the horizontal distances between those points and the apex, to be used as the bases in a diagram of triangles similar to that shown in Fig. 267, while V Z′ gives their hight. Having drawn a diagram of triangles the pattern follows in the manner there shown.

For greater accuracy in the case of a very tapering cone, the circles of the plan can be completed, as shown dotted, and their points of intersections with the line Z N can be dropped into oblique elevation, as seen at S and T, through which a line can be drawn to meet a line through F and H with greater accuracy than one through Y′ and X′, as the angle in the former case is twice as great.

In the above methods of obtaining the envelopes of what may be termed irregular conical forms, it will be clearly seen that the operation of dividing the curve of the base into a great number of spaces really resolves the conical figure into a many sided pyramid, and that the lines connecting the apex with the points in the base, which have been referred to as hypothenuses, are really the angles or hips of the pyramid. It is therefore self evident that any method of development which is applicable to a many sided pyramid is equally applicable to one whose sides are fewer in number, with the only difference, however, that the lines representing the angles or hips in the case of a pyramidal figure mean angles or sharp bends in the pattern of the envelope, while in the case of the conical envelope the bends are so slight as to mean only a continuous form or curve.

It is believed that the foregoing elucidation of the principles governing the development of the surfaces of irregular shaped figures is sufficiently clear to make the demonstrations of this class of problems, given in Chap. VI, Section 3, easily understood by the student, as well as to enable him to apply them to any new forms that may present themselves for solution.

This chapter is intended to present, under its three different heads, all the principles necessary to guide the student in the solution of any problem that may

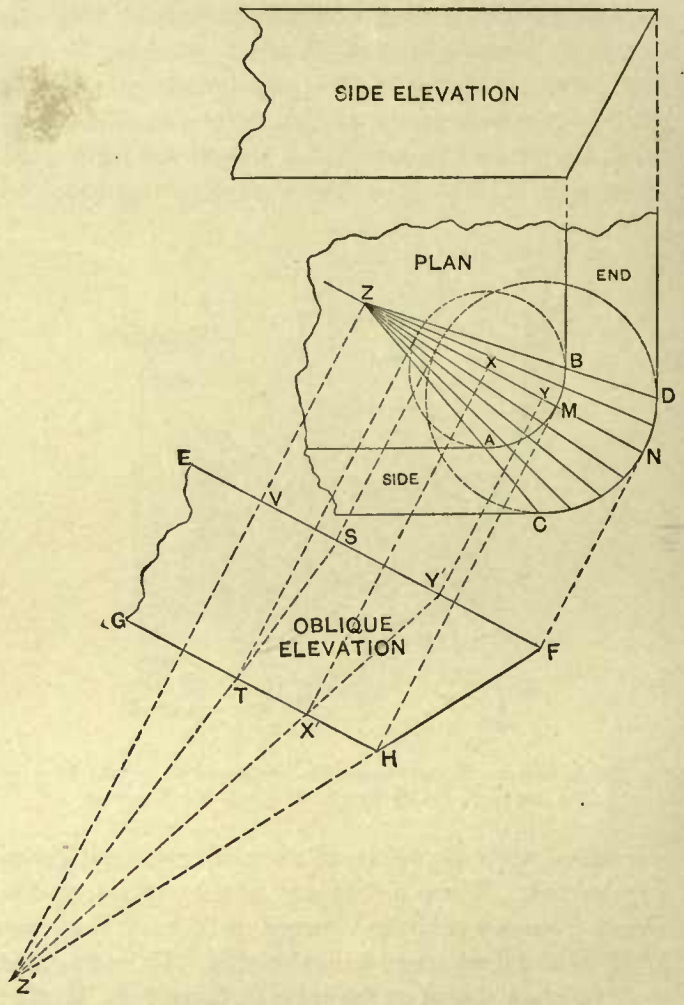
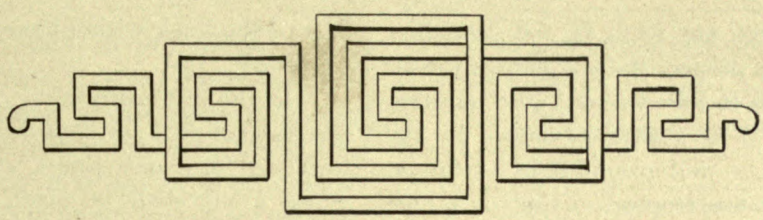


Fig. 271.—Elevations and Plan of an Article the Corner of which is a Portion of a Scalene Cone.

arise. Its aim is to teach principles rather than rules, and the student is to be cautioned against arbitrary rules and methods for which he cannot clearly understand the reason. His good sense must govern him in the employment of principles and in the choice of methods. There is hardly a pattern to be cut which cannot be obtained in more than one way. Under some conditions one method is best, and under other conditions another, and careful thought before the

drawing is begun will show which is best for the purpose in hand.

The list of problems and demonstrations in the chapter which follows is believed to be so comprehensive that therein will be found a parallel to almost anything that may be required of the pattern cutter, and it is believed that he will have no difficulty in applying them to his wants.



CHAPTER VI.

Pattern Problems.

Every effort has been put forth in the preceding chapters of this book to prepare the student for the all important work which is to follow—viz., the solution of pattern problems. It is always advisable in the study of any subject to be well grounded in its fundamental principles. For this reason a chapter on Linear Drawing has been prepared to meet the requirements of the student in pattern cutting, which is preceded by a description of drawing materials and followed by a solution of the geometrical problems of most frequent occurrence in his work. But the most important chapter is the one immediately preceding this, in which the theory of pattern cutting is explained, and which, if thoroughly understood, will render easy the solution of any problem the student may chance to meet.

The selection of problems here presented is made sufficiently large and varied in character to anticipate, so far as possible, the entire wants of the pattern cutter, and the problems are so arranged as to be convenient for reference by those who make use of this part of the book without previous study of the other chapters.

In the demonstrations, only the scientific phase of the subject will be considered; consequently, all allowances for seams, joints, etc., as well as determining where joints shall be made, are at the discretion of the workman. In some of the problems it has been necessary to assume a place for a joint, but if the joint is required at a place other than where shown, the method of procedure would be slightly varied while the principle involved would remain the same.

Each demonstration will be complete in itself, although references to other problems, principles, etc., will be made where such references will be of advantage to the student.

As stated in the preceding chapter, the problems will be classed under three different heads according to the forms which they embody—viz.: First, **Parallel Forms;** Second, **Regular Tapering Forms,** and Third, **Irregular Forms.**

SECTION 1.

Parallel Forms.

(MITER CUTTING).

The problems given in this section are such as occur in joining moldings, pipes and all regular continuous forms at any angle and against any other form or surface, and in fact include everything that may legitimately be termed *Miter Cutting.*

In the problems of this class *two* conditions exist, which depend upon the nature of the work. According to the *first*, a simple elevation or plan of the intersecting parts shows the miter line in connection with the profile, which is all that is necessary to begin at once with the work of laying out the patterns.

It frequently happens, however, that moldings are brought obliquely against sloping or curved surfaces in such a manner that no view can be drawn in which the miter line will appear as a simple straight line. Hence it becomes necessary to produce by the intersection of lines a correct elevation of the intersections of the various members of the molding, which when done results in the much sought miter line. Or it may be necessary to develop a correct profile of some oblique member or molding in order to effect a perfect miter. Thus some preliminary drawing must be done before the work of laying out the miter patterns can be properly begun, which constitutes the *second* condition above referred to and forms the great reason why the pattern draftsman should understand the principles of projec-

tion, which have been simplified for his benefit in Chapter III.

In the arrangement of the problems those which fulfill the first condition will precede those of the second, and all of a similar nature will, so far as possible, be placed near together, so that the reader, knowing the kind that is wanted, will be able to find it with little difficulty. It will also be to his advantage before reading any of the problems in this chapter to read carefully the Requirements and the general Rule governing this class of problems given in Chapter V on pages 76 and 77.

PROBLEM 1.

A Butt Miter Against a Plain Surface Oblique in Elevation.

Let A B L K in Fig. 272 be the elevation of a portion of a cornice, of which C D is the profile and A B the angle or inclination of the surface against which the cornice is required to miter. Divide the curved parts of the profile into spaces in the usual manner, and from all points in profile draw lines parallel with A K, cutting the miter line A B. On any convenient line, as E F, at right angles to the cornice, lay off a stretchout of the profile C D, space by space as they occur, through the points in which draw the measuring lines, all as indicated by the small figures. Placing the T-square at right angles to the lines of the cornice, or, what is the same, parallel to the stretchout line, bring it successively against the points in the miter line A B and cut measuring lines of corresponding number, as indicated by the dotted lines. A line traced through these points, as indicated by H G, will be the pattern required.

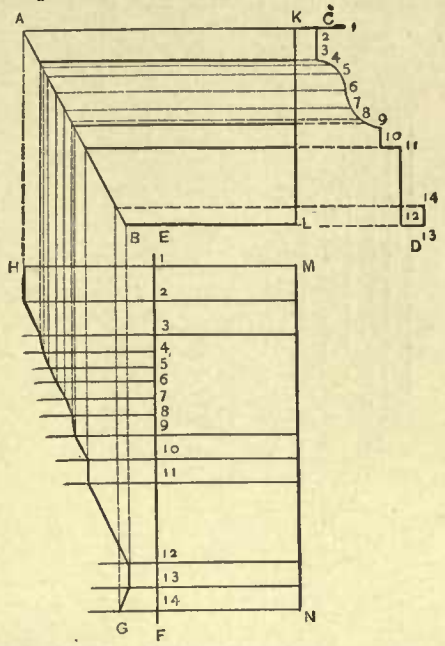


Fig. 272.—A Butt Miter Against a Plain Surface Oblique in Elevation.

PROBLEM 2.

A Butt Miter Against a Plain Surface Oblique in Plan.

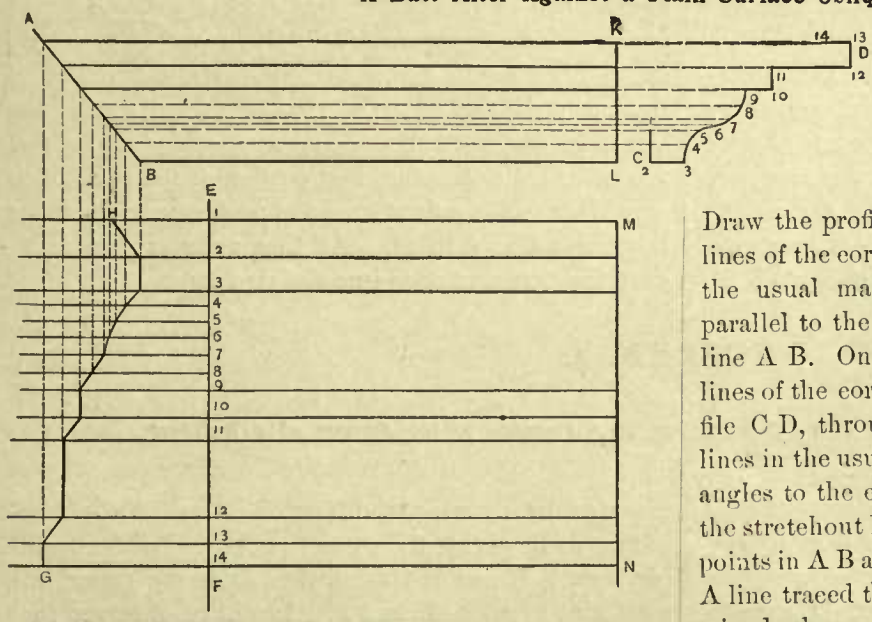


Fig. 273.—A Butt Miter Against a Plain Surface Oblique in Plan.

Let A B L K in Fig. 273 be the plan of the cornice which is required to miter against a vertical surface standing at any angle with the lines of the cornice, the angle being shown by A B. Draw the profile C D in position corresponding to the lines of the cornice, all as indicated. Space the profile in the usual manner, and through the points draw lines parallel to the direction of the cornice, cutting the miter line A B. On any convenient line at right angles to the lines of the cornice lay off the stretchout E F of the profile C D, through the points in which draw measuring lines in the usual manner. Placing the T-square at right angles to the cornice, or, what is the same, parallel to the stretchout line E F, bring it successively against the points in A B and cut the corresponding measuring lines. A line traced through the points of intersection thus obtained, shown by H G, will be the pattern required.

PROBLEM 3.

A Square Return Miter, or a Miter at Right Angles, as in a Cornice at the Corner of a Building.

In Fig. 274, let A B D C be the elevation of a cornice at the corner of the building for which a miter at right angles is desired. As has been explained in the chapter on the Principles of Pattern Cutting (page 77), the process of cutting a miter for a right angle admits of certain abbreviations not employed when other

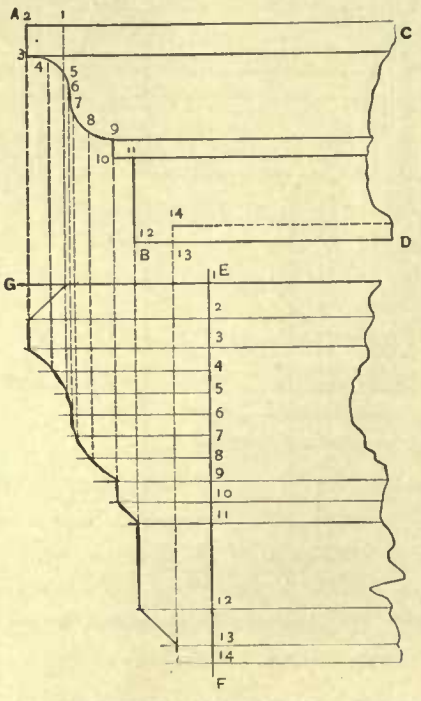


Fig. 274.—A Square Return Miter, as in a Cornice at the Corner of a Building.

angles are required. The demonstration here introduced is calculated to show the method of obtaining the pattern for a square miter with the least possible labor. Divide the profile A B into any convenient number of parts, as shown by the small figures. At right angles to the lines of the molding, and in convenient proximity to it, lay off the stretchout E F, through the points in which draw measuring lines in the usual manner, parallel to the lines of the cornice, producing them far enough to intercept lines dropped vertically from points in A B. Place the T-square at right angles to the cornice, or, what is the same, parallel to the stretchout line, and, bringing it successively against all the points in the profile A B, cut measuring lines of corresponding numbers. Then a line traced through these points, as shown by G H, will be the pattern sought. The reason for this is as follows: As the angle of this miter cannot be shown in any other view than a plan, the plan is the correct view from which to derive the pattern; having drawn which, as

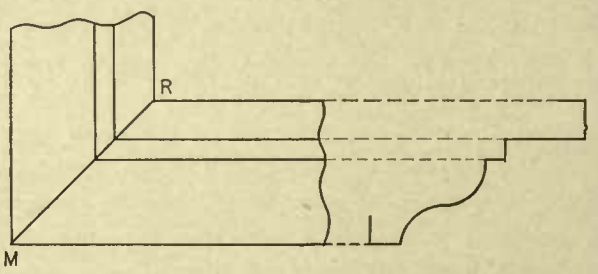


Fig. 275.—Plan of a Square Return Miter.

shown in Fig. 275, the operation of developing the pattern becomes exactly the same as in the previous problem (Fig. 273). In Fig. 274, A B D C represents the elevation of a portion of a cornice, while A B represents the profile of the return or receding portion against which the piece A B D C is required to miter, or, in other words, the miter line. As the profiles of the face piece and of the return piece are of course the same, the outline A B becomes at once the profile and the miter line; therefore that portion of the rule which says, "drop the points from the profile on to the miter line," must be omitted. All that remains then is to drop the points at once into the stretchout.

PROBLEM 4.

A Return Miter at Other Than a Right Angle, as in a Cornice at the Corner of a Building.

In Fig. 276, let A B C D be the elevation of a portion of cornice, and let G H K be the plan of any angle around which the cornice is to be carried, a pattern being required for an arm of the miter. Complete the plan by drawing the lines E F and F L, intersecting at F, giving the correct projection of the molding from G H and H K, and then draw the miter line between the points H and F. It will be observed that

the arm G H F E has been projected directly from the profile A B, thus placing profile and plan in correct relation to each other. Divide the profile A B in the usual manner into any convenient number of parts, and from the points thus obtained drop lines vertically on to the miter line in the plan F H, as shown. At right angles to this arm of the cornice, as shown in plan, lay off a stretchout of the profile, as shown by N M, through the points in which draw the usual measuring lines, as indicated. Place the T-square parallel to this line, or, what is the same, at right angles to E F, and, bringing it successively against the points in F H, cut measuring lines of corresponding numbers. Then a line traced through the points thus obtained, as shown by O P, will be the pattern sought. As intimated at the outset of this problem, the angle G H K represents any angle whatever, and the course to be pursued is exactly the same whether it be acute or obtuse. Of course the more acute the angle G H K the longer will the miter line H F become, as may be ascertained by experiment, producing a corresponding increase in the projection of the different parts of the pattern from the line N M.

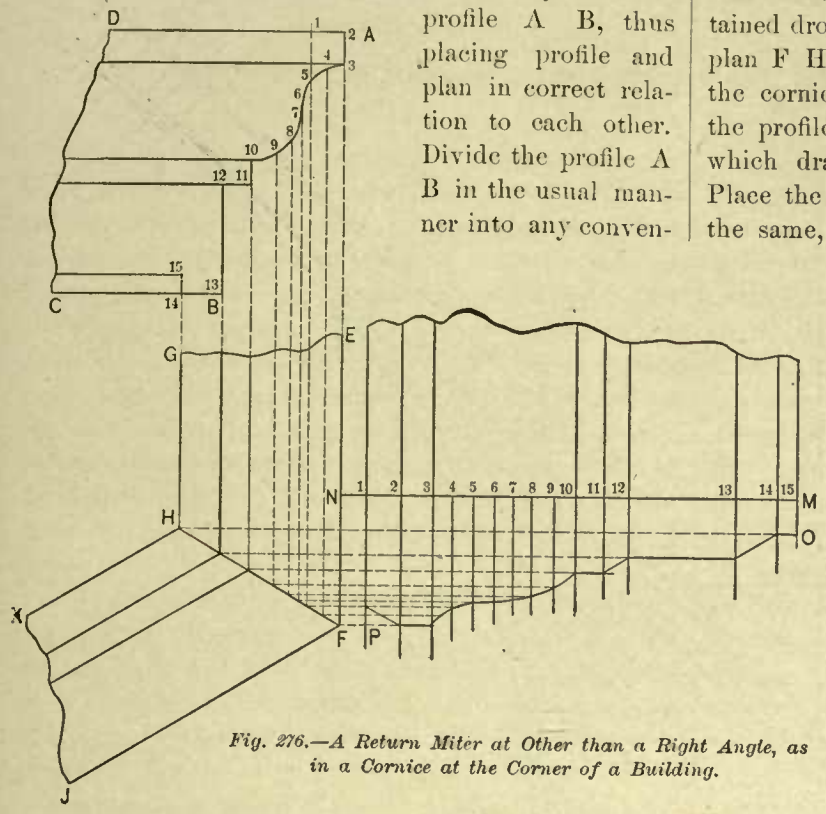


Fig. 276.—A Return Miter at Other than a Right Angle, as in a Cornice at the Corner of a Building.

PROBLEM 5.

A Butt Miter Against a Curved Surface.

In Fig. 277, let A B be the profile of any cornice and D K H C be the elevation of the same showing the curved surface C D, against which it is required to miter. The principle herein involved is exactly the same as that in Problem 1. Space the profile in the usual manner, and through the points draw lines cutting C D. At right angles to the line of cornice lay off the stretchout L M, as shown, through the points in which draw measuring lines in the usual manner. Place the T-square parallel to the stretchout line, or, what is the same, at right angles to the lines of the cornice, and, bringing it against the several points in C D, cut the corresponding measuring lines, as shown. In the event of a wide space, as shown by a' b' in the elevation, the curve between these points may be transferred to the pattern by means of a piece of tracing paper, or, if it is a regular curve, its radius may be used as shown by G and G′ and the arrow points. A line traced through the several points of intersection, as shown by E F, will be the shape of the required pattern.

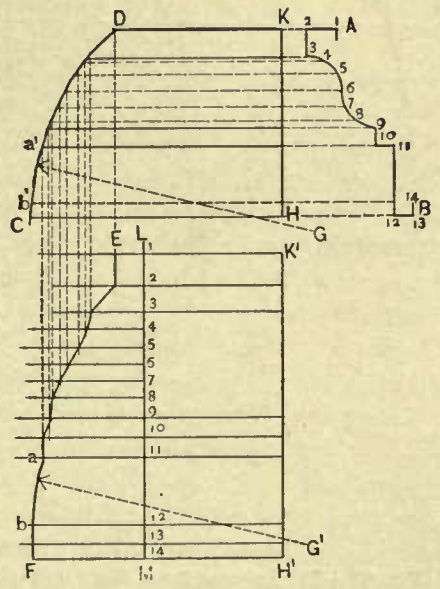


Fig. 277.—A Butt Miter against a Regular Curved Surface.

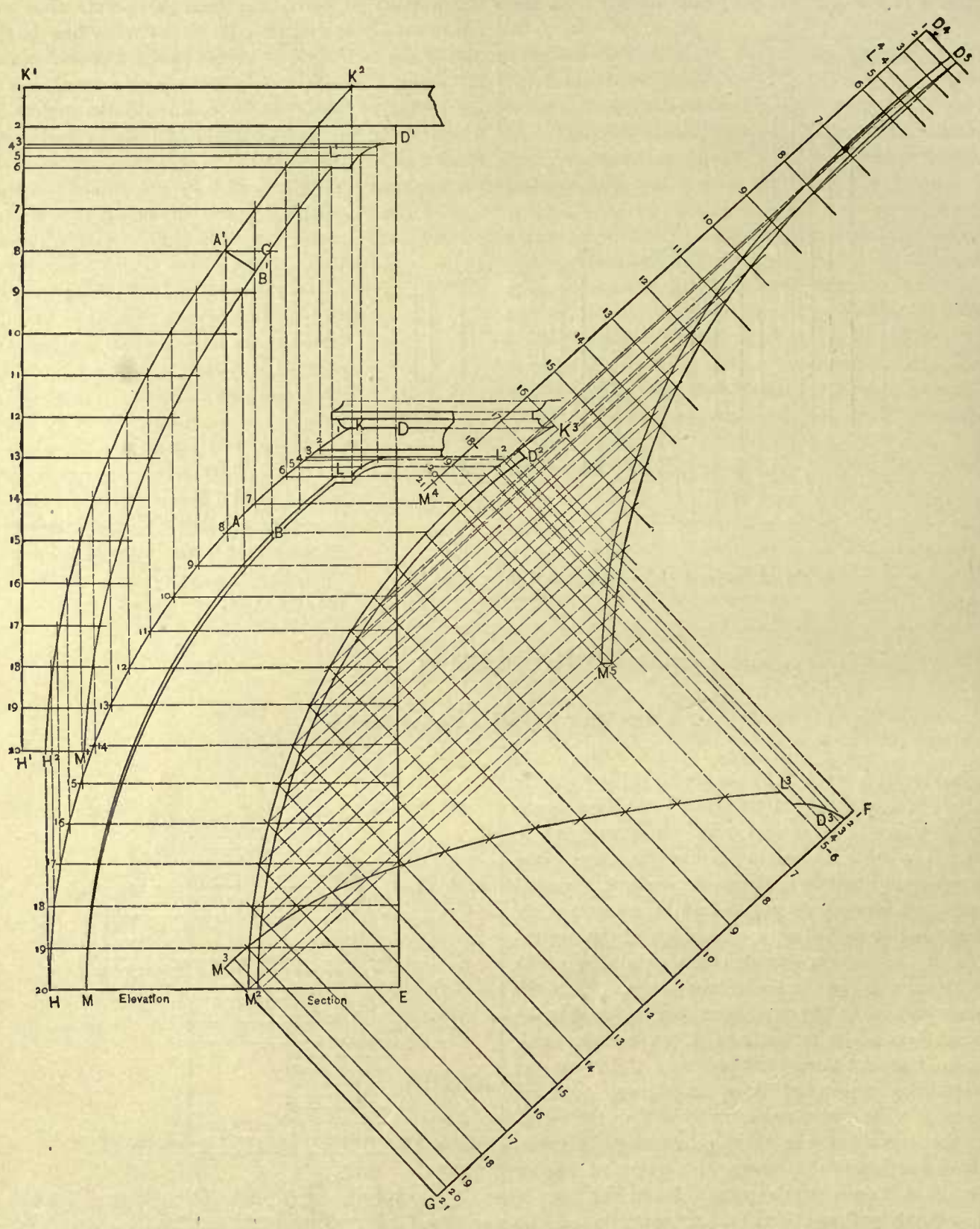


Fig. 278.—The Patterns for a Hip Finish in a Curved Mansard Roof, the Angle of the Hip being a Right Angle.

PROBLEM 6.

The Pattern for a Hip Finish in a Curved Mansard Roof, the Plan of the Hip Being a Right Angle.

The solution of all problems concerning mansard roofs, and especially those in which the roof surface is curved, calls for much good judgment on the part of the pattern cutter, for the reason that the original designs that come into his hands are seldom drawn mathematically correct. The upper part of a mansard dome, such as is shown in Fig. 278, as it curves away from the eye, becomes so much flattened in appearance that, if drawn correctly, it might, to any but an expert draftsman, create a false impression of the design intended; hence the original drawing must often be taken for what it means rather than for what it says.

The engraving represents an elevation of a curved hip molding occurring in a roof, of which E D is the vertical hight and M^2 K^2 is a section. The first step to be described is the method of obtaining the pattern of the fascias of the hip molding. For this purpose is shown in the drawing such a representation of it as would appear if the two fascias formed a close joint upon the angle of the roof, supposing that the hip molding or the bead is to be added afterward on the outside over this joint. The part to be dealt with may be considered the same as though it were the section of a molding, instead of a section of a roof, and the operations performed are identical with those employed in cutting a square miter. Space the profile H K into any convenient number of parts, introducing lines in the upper part in connection with the ornamental corner piece, shown by L D, at such intervals as will make it possible to take measurements required to describe the shape of it in the pattern. From this profile, by means of the points just indicated, lay off a stretchout, as shown by H^1 K^1, and through the points draw the usual measuring lines. Bring the T-square against the several points in H K, and cut the corresponding lines drawn through the stretchout just described. Then a line traced through these points, as shown by H^2 K^2, will be the outside line of the fascia. For the inside line take the given width of the fascia and set it off from this line at intervals, measuring at right angles to it, as indicated by A^1 B^1, and not along the measuring lines of the stretchout, as would be indicated by A^1 C. Then a line traced through these points, as shown from M^1 to L^1, will be the inside line of the fascia strip. The points in the ornamental corner piece from L^1 to D^1 are to be obtained from the elevation, in case a correct elevation is furnished the pattern cutter, by measurement along the lines drawn horizontally through the several points in L D, which are transferred to the measuring lines of corresponding number in the stretchout already referred to. Or the shape from L^1 to D^1 may be described arbitrarily upon the pattern at this stage of the operation, according to the finish required upon the roof. The latter method is the preferable one. The method of constructing the elevation, by working back from the outline thus established, is clearly indicated by the dotted lines in the engraving. From the several points in the profile H K horizontal lines are drawn, as shown, and from the intersections of the inside line of the pattern of the fascia piece with the various measuring lines, as above described, lines are dropped, cutting these horizontal lines of corresponding numbers. Then a line traced through these points, shown from M to L, will be the inside line of the fascia piece in elevation. To cut the flange strip bounding the fascia and corner piece, commonly called the sink strip, an elevation of which is shown in the section from M^2 to D^2, the following method will be the simplest, and at the same time sufficiently accurate for all purposes: Draw the line G F approximately parallel to the upper part of the section M^2 D^2, making it indefinite in length, which cut by lines drawn from the several points in M^2 D^2, at right angles to it, as shown. From F G, upon the several lines drawn at right angles to it, set off spaces equal to the distance upon lines of corresponding number from D E to the line M L of the elevation. Then a line traced through these points, as indicated by M^3 L^3, will constitute a profile of this flange strip. In like manner set off in continuation of it, the lengths measured from points in the ornamental corner piece to D E, all as shown by L^3 D^3 F. From this profile lay off a stretchout parallel to G F, as shown by M^4 D^4, through the points in which draw measuring lines in the usual manner. Place the T-square parallel to the stretchout line, and, bringing it successively against points in both the inner and the outer lines of the elevation of the flange strip, as shown from M^2 D^2, cut the measuring lines of corre-

sponding number. Then lines traced through these points of intersection, as shown from M⁵ to D⁶, will be the pattern of the flange strip bounding the edge of the fascia.

PROBLEM 7.

Miter Between Two Moldings of Different Profiles.

To construct a square miter between moldings of dissimilar profiles requires two distinct operations. The miter upon each piece is to be cut as it would appear when intersected by the other molding. Let A B and A' B' in Figs. 279 and 280 be the profiles of two moldings, between which a square miter is required. As, of course, the two arms of the miter are different, it will be necessary to draw an elevation of each showing the proper outline against which it is to miter. Beginning, therefore, with the profile A B, project from it an elevation, as shown by F C D E, Fig. 279, terminating such elevation by the profile of the other molding, A' B', as shown by F E. Then, as in the case of Problems 1 and 6, the line F E becomes the miter line, and the method of procedure is the same as in those problems. Divide A B into any convenient number of parts in the usual manner, from which carry lines horizontally against F E. At right angles to the lines of the molding lay off a stretchout, G H, of the profile A B, through the points in which draw the usual measuring lines. Bring the T-square against the points of intersection in the line E F, and cut the corresponding measuring lines. Then a line traced through these points, as shown by F' E', will give the shape of the cut on the piece A B to fit against the profile E F. For the other piece proceed in the same manner, reversing the order of the profiles. From its profile A' B' produce the elevation K M N L, Fig. 280, completing same by means of the profile of the first molding, A B, as shown by M N. Divide A' B' in the usual manner. Through the points draw lines cutting M N. At right angles to this piece lay off the stretchout O P of the profile A' B', through the points in which draw measuring lines, as shown. With the T-square at right angles to the line K M or N L, and brought against the points in M N, cut corresponding measuring lines drawn through O P. A line traced through these points, as shown by M' N', will be the shape of the end of the piece required to fit against the profile M N. In the event of the points obtained by spacing the profiles A B and A' B' not meeting all the points in the profiles F E and M N necessary to be marked in the pattern, then lines must be drawn backward from such points in profiles M N and E F, cutting the profile A' B' or A B, as the case may be. Corresponding points are then to be inserted in the

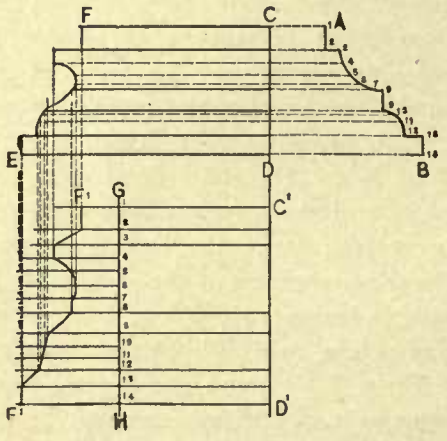


Fig. 279.

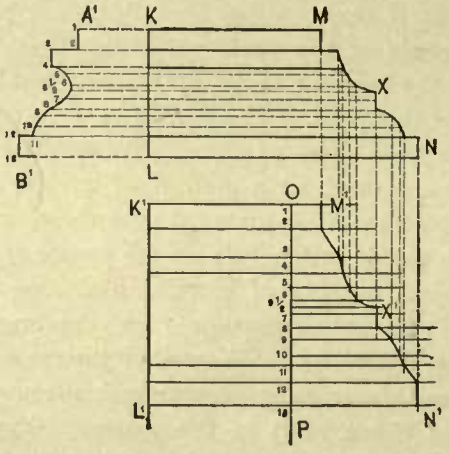


Fig. 280.

Miter between Two Moldings of Different Profiles.

stretchouts, through which measuring lines are to be drawn, which, in turn, are to be intersected by lines dropped from the points. An illustration of this occurs in Fig. 280, where it will be seen that no point obtained by the dividing of the profile A' B' strikes the point X of the miter line, which is absolutely necessary to the shape of the pattern. Therefore, after spacing the profile, a line is drawn from X back to A' B', foring the point No. 6½. In turn this point is transferred to the stretchout O P, also marked 6½, from which a measuring line is drawn in the same manner as through the other points in the stretchout, upon which a point from X is dropped, as shown by X'. In actual practice such expedients as this must be resorted to in almost every case, because usually there is less correspondence between the members of dissimilar profiles, between which a miter is required, than in the illustration here given. By this means profiles, however unlike, can be joined.

PROBLEM 8.

A Butt Miter Against an Irregular or Molded Surface.

Let B A in Fig. 281 be the profile of a cornice, against which a molding of the profile, shown by G H, is to miter, the latter meeting it at an inclination, as indicated by C D. Construct an elevation of the oblique molding, as shown by C D F E, in line with which draw the profile G H. Divide G H in the usual manner into any convenient number of parts, and through the points draw lines parallel to the lines of the inclined molding, cutting the profile B A, all as indicated by the dotted lines. At right angles to the lines of the molding, of which a pattern is sought, lay off a stretchout, M N, in the usual manner, through the points in which draw measuring lines. Place the T-square at right angles to the lines of the inclined molding, or, what is the same, parallel to the stretchout line, and, bringing it against the points of intersection formed by the lines drawn from the profile G H across the profile B A, cut the corresponding measuring lines. In the event of any angles or points occurring in the profile B A which are not met by lines drawn from the points in G H, additional lines from these points must be drawn, cutting the profile G H, in order to establish corresponding points in the stretchout. Thus the points 3 and 13 in the profile G H are inserted after spacing the profile, as described in Problem 7, because the points with which they correspond in the profile B E are angles which must be clearly indicated in the pattern to be cut. Having thus cut the measuring lines corresponding to the points in the profile B A, draw a line through the points of intersection, as shown by O P. Then O P will be the shape of the pattern of the incline cornice to miter against the profile A B.

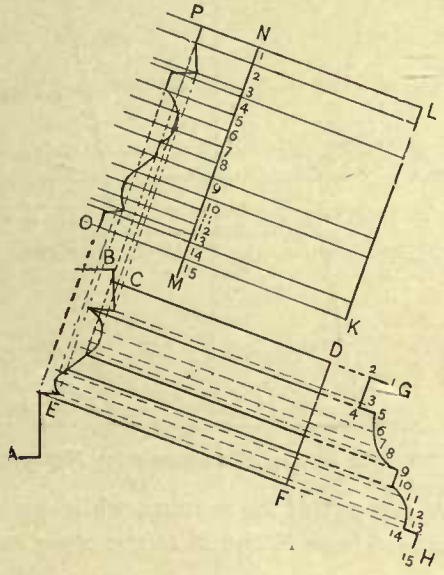


Fig. 281.—A Butt Miter against an Irregular or Molded Surface.

PROBLEM 9.

The Pattern of a Rectangular Flaring Article.

In Fig. 282, let C A B E be the side elevation of the article, of which F I K M is the plan at the base and G H L N the plan at the top. Let it be required to produce the pattern in one piece, the top included. Make H' L' N' G' in all respects equal to H L N G of the plan. Through the center of it likewise draw R P indefinitely, and through the center in the opposite direction draw O S indefinitely. From the lines H' L' and G' N' set off T O and W S respectively, each in length equal to the slant hight of the article, as shown by C A or E B of the elevation. Through O and S respectively draw I' K' and F' M', parallel to H' L' and G' N', and in length equal to the corresponding sides in the plan I K and F M, placing one-half that length each way from the points O and S. In like manner set off V P and U R, also equal to C A, and draw through R and P the lines F² I² and K² M², parallel to the ends of the pattern of the top part as already drawn, and in length equal to I F and K M of the plan. Draw I' H', K' L', K² L', M² N', M' N', F' G', F² G' and I² H', thus completing the pattern sought. In the same general way the pattern may be described, including the bottom instead of the top, if it be required that way.

Considering this problem in the light of miter cutting proper, I H G F and F G N M may be regarded as the plan of two similar moldings of which A C is the profile, I H, G F and N M being the miter lines. O T is the stretchout line, drawn at right angles to F M, while I' K' and H' L' are the measuring lines representing respectively the points C and A of the profile.

The points F and G are then dropped into their respective measuring lines, thus locating the points I'

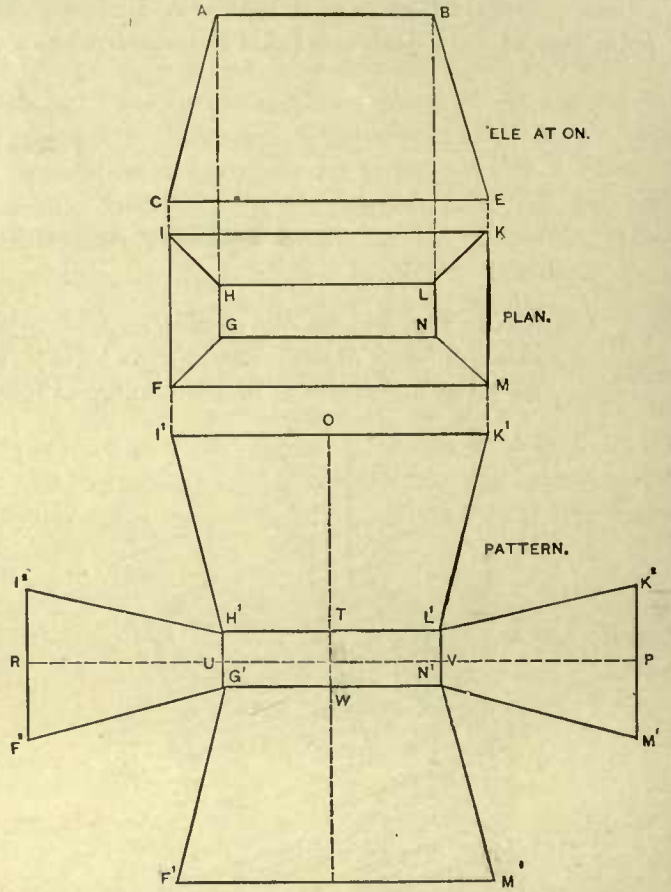


Fig. 282.—The Pattern of a Rectangular Flaring Article.

and H' at one end of the pattern, while points K' and L' are derived from M and N at the other end.

PROBLEM 10.

Patterns of the Face and Side of a Plain Tapering Keystone.

Let A B D C in Fig. 283 be the elevation of the face of a keystone, and G E² F² K of Fig. 284 a section of the same on its center line.

Sometimes problems occur which are so simple that it is not apparent that their solution is an exemplification of any rule. That this, with others in which plain surfaces form the largest factors, may be so designated, will be sufficient excuse for a brief reference to first principles. This problem is generally referred to as finding the "true face" of the keystone, because, the face being inclined, the elevation A B C D does not represent the "true face" or "true" dimensions of the face. To state the case, then, in conformity with the rule, A B and C D are the upper and

lower lines of a molding, of which E^2 F^2 of Fig. 284 is the profile, and A C and B D are the surfaces against

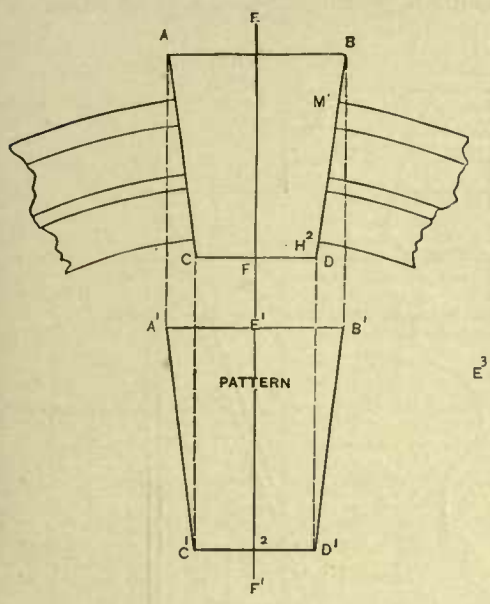


Fig. 283.

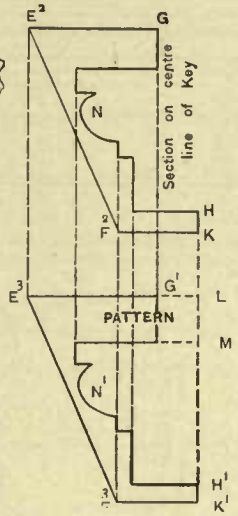


Fig. 284.

Patterns of the Face and Side of a Plain Tapering Keystone.

which it miters, or the miter lines. Therefore, to lay out the pattern, draw any line, as E' F', at right angles to A B for a stretchout line, upon which lay off the stretchout taken from the profile E^2 F^2, Fig. 284, which in this case consists of only one space, as shown by E' F'; through the points E' and F' draw the horizontal lines A' B' and C' D', which are none other than the measuring lines. Then, with the T-square placed parallel with the stretchout line, drop the points from the miter lines A C and B D into lines of corresponding letter, which connect, as shown by A' C' and B' D', which completes the pattern.

In developing the pattern for the side, E^2 G and F^2 K are the lines of the molding, B D of Fig. 283 its profile and E^2 F^2 the miter line. Hence upon any vertical line, as L K', lay off the stretchout of profile B D, locating the points M' and H^2, all as shown by L M H' K', through which points draw the measuring lines; then, with the T-square placed parallel to L K', drop the points E^2 and F^2 into lines of corresponding letter, as shown by E^2 F^2. As the vertical lines at G and K represent the position of surfaces against which the side is required to fit at the back, bring the T-square against each, thus locating them in the pattern at G' and K', as shown.

As the side must also fit over the molding of the arch an opening must be cut in it corresponding in shape to the profile of the arch molding N, which is given in the sectional view. It is therefore only necessary to transfer this profile to the pattern, placing the top at the measuring line M and the bottom at the measuring line H', all as shown at N'.

PROBLEM 11.

Patterns for the Corner Piece of a Mansard Roof, Embodying the Principles Upon Which All Mansard Finishes are Developed.

One of the first steps in developing the patterns for trimming the angles of a mansard roof is to obtain a representation of the true face of the roof. In other words, inasmuch as the surface of the roof has a slant equal to that shown in the profile of the return, the length of the hip is other than is shown in the elevation, and this difference in dimensions extends in a proportionate degree to the lines of the various parts forming the finish. Not only are the vertical and oblique dimensions different, but, as the result of this, the angle at A is different from that shown in a normal elevation. Hence, it is of the greatest importance to obtain a "true face" or elevation of the roof as it would appear if swung into a vertical position, which may be accomplished as follows:

In Fig. 285, let A E F C be the elevation of a mansard roof as ordinarily drawn, and let A' G be the profile showing the pitch drawn in line with the elevation. Set the dividers to the length A' G, and from A' as center, strike the arc G G', letting G' fall in a vertical line from A'. From G' draw a line parallel to the face of the elevation, as shown by G' C', and from the several points in the hip finish, as shown by C and K, drop lines vertically, cutting G' C' in the points C' and K', as shown. From these points carry lines to corresponding points in the upper line of the

elevation, as shown by C¹ A and K¹ *h*. Then A C¹ F¹ E represents the pattern of the surface shown by A C F E of the elevation. In cases where the whole hight of the roof cannot be put into the drawing for use, as above described, the same result may be accomplished by assuming any point as far from A as the size of the drawing will permit, as B, and treating the part between A and B as though it were the whole. That is, from A, in a vertical line, set off A B¹, equal to A B. From B¹ draw the horizontal line, as shown by B¹ B³, and from B drop a vertical line cutting this line, as shown, in the point B³. By inspection of the engraving it will be seen that the point B³ falls in the line A C¹ obtained in the previous operation, thus demonstrating that the latter method of obtaining the angle by which to proportion the several parts results the same as the method first described, and therefore may be used when more convenient.

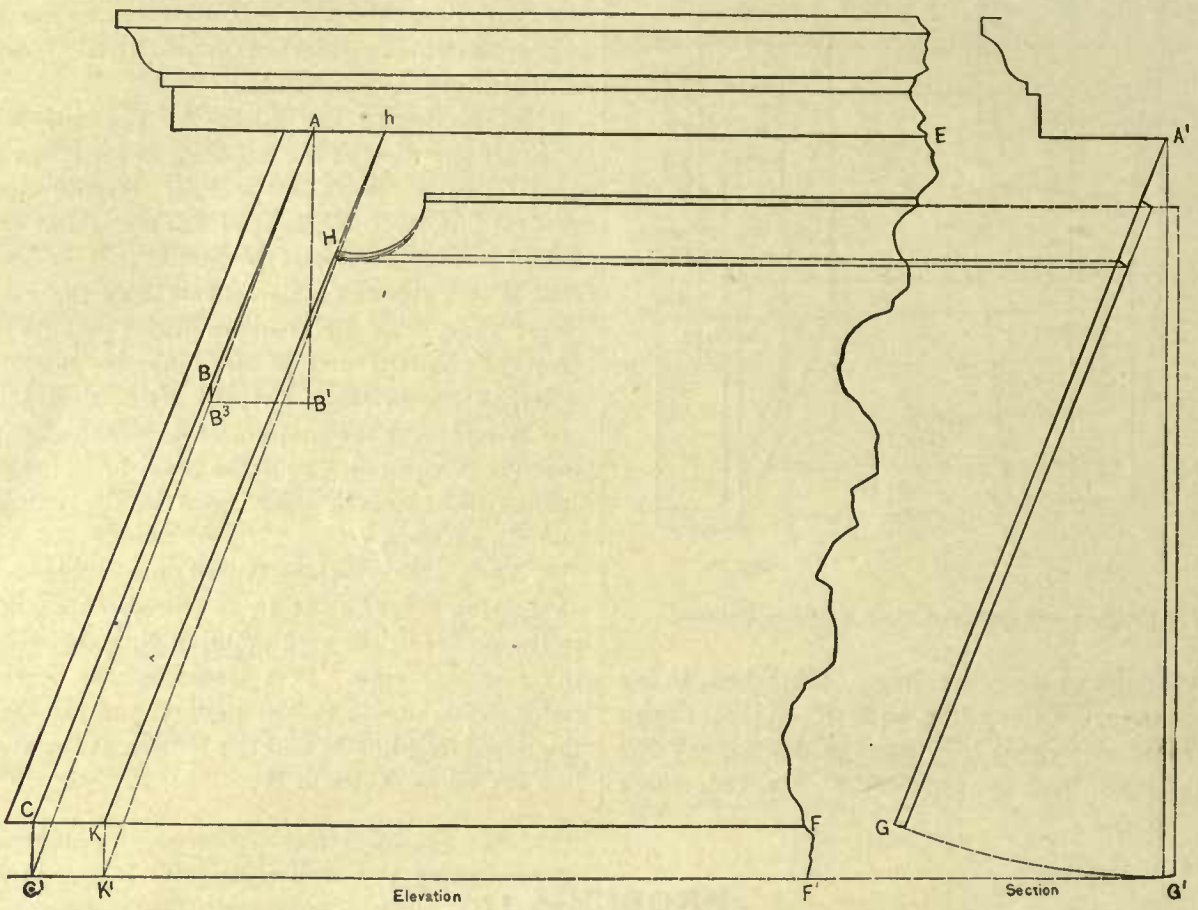


Fig. 285.—The Plain Surfaces of a Mansard Roof Developed.

PROBLEM 12.

A Face Miter at Right Angles, as in the Molding Around a Panel.

In Fig. 286, let A B D C represent any panel, around which a molding is to be carried of the profile at E and E¹. The miters required in this case are of the nature commonly called "face" miters, to distinguish them from other square miters, which can only be shown in a plan view. A correct elevation of the panel A B D C, with the lines of the molding carried around the same, determines the miter lines A F and G C, which, in connection with the profiles at E and E¹ are all that is necessary to the development of the pat-

tern. The two profiles are here drawn, thus constituting an entire section of the panel, because it is usual, for constructive reasons, to cut the two moldings with the intervening panel in one piece where the width of

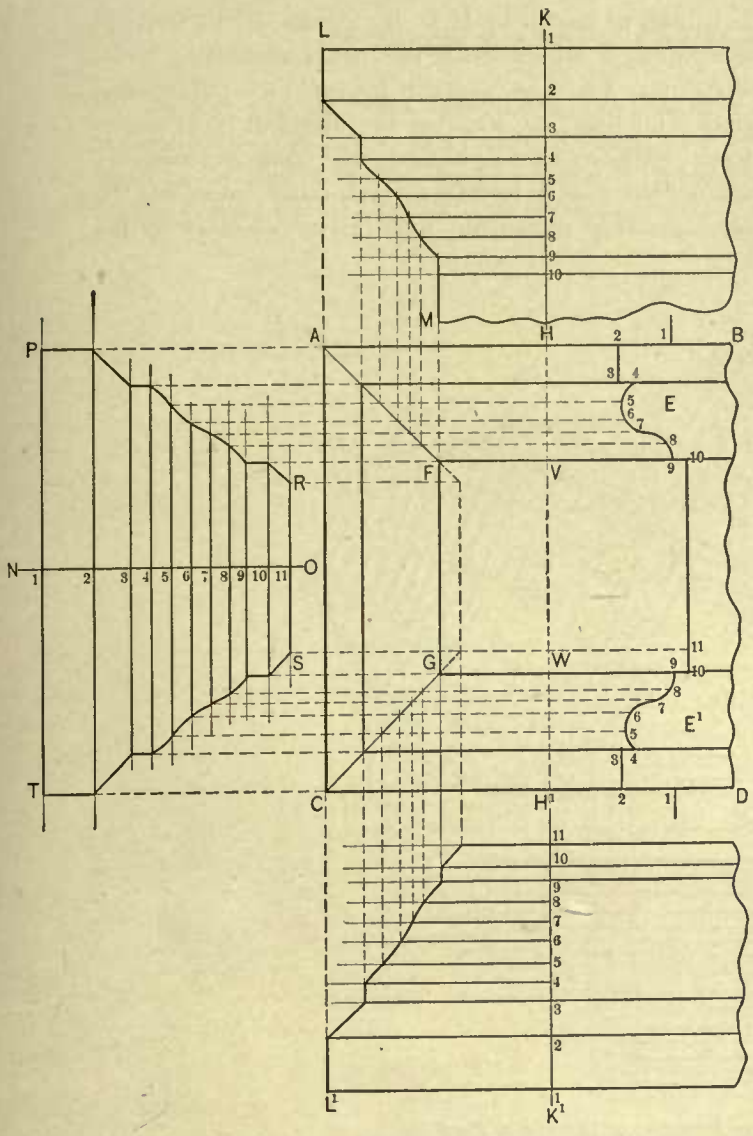


Fig. 286.—A Face Miter at Right Angles, as in the Molding Around a Panel.

the metal will permit it. Divide the two profiles in the usual manner into the same number of parts, from which points draw lines parallel to the lines of the molding, cutting the miter lines, as shown. For the pattern of the side corresponding to A B lay off a stretchout at right angles to it, as shown by H K, through which draw measuring lines in the usual manner. Place the T-square at right angles to A B, or, what is the same, parallel to the stretchout line H K, and, bringing it successively against the several points in the miter line A F, cut measuring lines of corresponding number. Then a line traced through these points, as shown by L M, will be the pattern sought. The other pattern is developed in like manner. It is usual to draw the stretchout lines, K H and K¹ H¹ across the lines of the moldings which they represent, beginning the stretchouts at the inner lines of the molding, thus: Point 10 of profile E would be located at V, while point 10 of profile E¹ would be at W. While this is apt to produce some confusion of lines in actual practice, it gives the entire profile in one continuous stretchout for the purpose alluded to above—that of cutting the entire width of the panel in one piece. Should it be desired to make one of the moldings separate from the rest, an additional point for the purpose of a lap is assumed at one of the moldings, as 11 of profile E¹. The pattern for the end piece, A C, may be derived without drawing an additional profile, as its profile and stretchout are necessarily the same as that of the other two arms; therefore reproduce H K on a line at right angles to A C, as shown by N O, through the points in which draw measuring lines in the usual manner, producing them sufficiently far in each direction to intercept lines dropped from the points in the two miter lines. Place the T-square at right angles to A C, and, bringing it successively against points already in A F and C G, cut measuring lines of corresponding numbers. Then lines traced through the intersections thus formed, as shown by P R and S T, will be the shape of the pattern of the end piece.

It may be noticed in the last operation that dropping the points from either of the miter lines, as A F, into the measuring lines is, in fact, only continuing in the same direction the lines previously drawn from the profile E to the line A F; and that in reality the shape of the cut at P R is developed without the assistance of the miter line, thus giving another instance of the fact that any square miter can be cut by the short method when the relation of the parts is understood.

PROBLEM 13.

The Patterns of the Moldings Bounding a Panel Triangular in Shape.

In Fig. 287, let D E F be the elevation of a triangular panel or other article, surrounding which is a molding of the profile, shown at G and G¹. Construct an elevation of the panel molds, as shown by A B C, and draw the miter lines A D, B E and C F. For the patterns of the several sides proceed as follows: Draw a profile, G, placing it in correct relative position to the side D F, as shown. Divide it into any convenient number of parts in the usual manner, and through these points draw lines, as shown, cutting the miter lines F C and A D. In like manner place the profile G¹ in a corresponding position relative to the side E F. Divide it into the same number of parts, and draw lines intersecting those drawn from the first profile in the line F C, also cutting the line E B. By this operation points are obtained in the three miter lines A D, E B, F C, from which to lay off the patterns in the usual manner. At right angles to each of the three sides, at convenient points, draw stretchout lines, as shown by H I, H¹ I¹ and H² I², through the points in which draw the usual measuring lines. With the T-square parallel to each of the several stretchout lines, or, what is the same, at right angles to the respective sides, bringing the blade successively against the points in the several miter lines, cut the corresponding measuring lines, all as indicated by the dotted lines. Then lines traced through the points of intersection thus obtained will describe the patterns required. A¹ C¹ F¹ D¹ will be the pattern for the side A D F C of the elevation, and likewise C² B² E² F² is the pattern for the side described by similar letters.

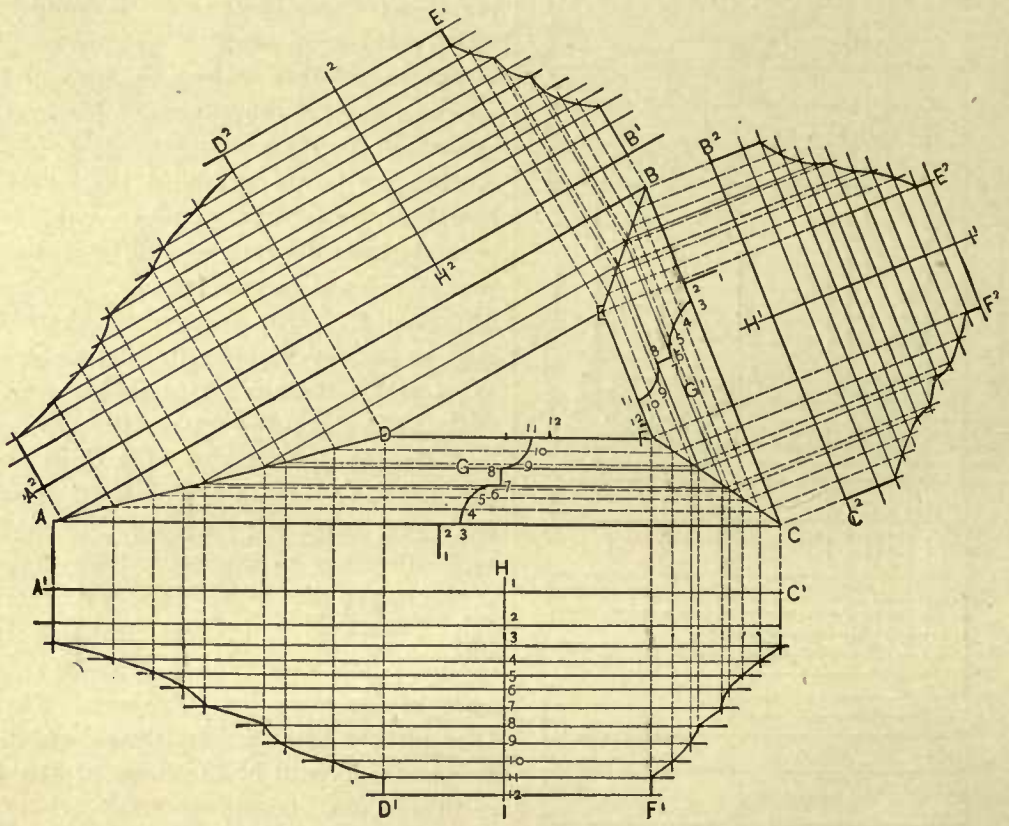


Fig. 287.—The Patterns of the Moldings Bounding a Triangular Panel.

Placing another profile in the molding A B D E would, if divided the same as the others, only result in another set of intersections at the points already existing on the lines A D and B E, as occurred on

the line F C, hence to save labor one profile in this case is all that is really necessary, the points being carried around from that and dropped into the three stretchouts respectively.

PROBLEM 14.

The Patterns of a Molding Mitering Around an Irregular Four-Sided Figure.

In Fig. 288, let A B C D be the elevation of an irregular four-sided figure, to which a molding is to be fitted of the profile shown by K. Place a duplicate profile against the side opposite, as shown, from which in these several stretchouts draw measuring lines in the usual manner, producing them until they are equal in length to the respective sides, the pattern of which is to be cut. Placing the T-square at right angles to the

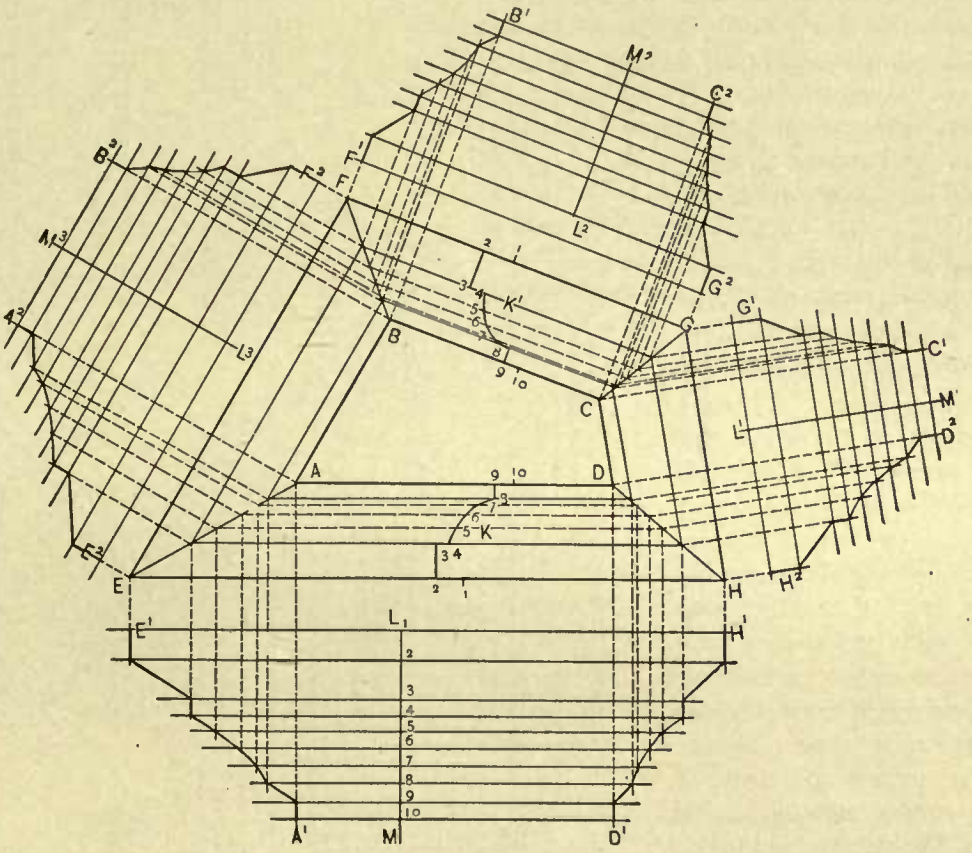


Fig. 288.—The Patterns of a Molding Mitering Around an Irregular Four-Sided Figure.

project the lines necessary to complete the elevation of the molding as it would appear when finished, all as shown by E F G H. Draw the several miter lines B F, C G, D H and A E. Divide the two profiles into the same number of parts in the usual manner, through the points in which draw lines parallel to the lines of the molding in which they occur, cutting the miter lines, as shown. At right angles to each of the several sides lay off a stretchout from the profile, as shown by L M, L' M', L² M², L³ M³. Through the several points lines of the several sides, or, what is the same, parallel to the stretchout lines, bring it against the points in the miter lines, cutting the corresponding measuring lines, all as indicated by the dotted lines. Then the lines traced through these points of intersection will give the several patterns required. Thus E' H' D' A' will be the pattern of the side E H D A of the elevation; H² D² C' G' will be the pattern of the side H D C G; G² F' B' C² that of F B C G; and F² B² A' E² that of the remaining side.

PROBLEM 15.

The Patterns of Simple Gable Miters.

In Fig. 289, let A B K and B K R be the angles of the miters at the foot and peak of a gable. Draw profiles of the required molding in correct relation to both the horizontal and inclined moldings, as shown at H and H', through the angles of which draw the other parallel lines necessary to complete the elevation. Their intersection at the base of the gable produces the miter line B C, while the miter line at the top of the gable is a vertical line, because the two sides of the gable, K B and K R, are of the same pitch. The profile H is so placed as also to represent the return at the side at its proper distance from B. Divide the profile H in the usual manner into any convenient number of equal parts. Place the T-square parellel to the lines in the horizontal molding, and, bringing it successively against the points in the profile, cut the miter line B C, as shown. At right angles to the lines of the horizontal cornice draw the stretchout E F, through the points in which draw the usual measuring lines, as shown. Reverse the T-square, letting the blade lie parallel to the stretchout line E F, and, bringing it against the several points of the profile H, cut the corresponding measuring lines. Then a line traced through these points of intersection, as shown from G to V, will be the pattern of the end of the horizontal cornice mitering with the return. In like manner, with the T-square in the same position, bring it against the points in the miter line B C, and cut corresponding measuring lines drawn through the same stretchout. Then a line traced through the points of intersection thus obtained, as shown by T U, will be the pattern of the end of the horizontal cornice mitering against the inclined cornice. Divide the profile H' into any convenient number of equal parts, all as indicated by the small figures. Through these points draw lines cutting the miter line B C, and also the miter line K L at the top. At right angles to the lines of the raking cornice place a stretchout, E' F', of the profile H', through the points in which draw the usual measuring lines, as shown. Place the T-square parallel to this stretchout line, and, bringing it successively against the points in B C and K L, cut the corresponding measuring lines, all as indicated by the dotted lines. Through the points thus obtained trace lines, as indicated by M N and O P. Then M N will be the pattern for the bottom of the raking cornice mitering against the horizontal, and O P will be the pattern for the top of the same. The pattern shown at G V will also be the pattern for the return mitering with A D of the elevation, it being necessary only to reverse it and to establish its length.

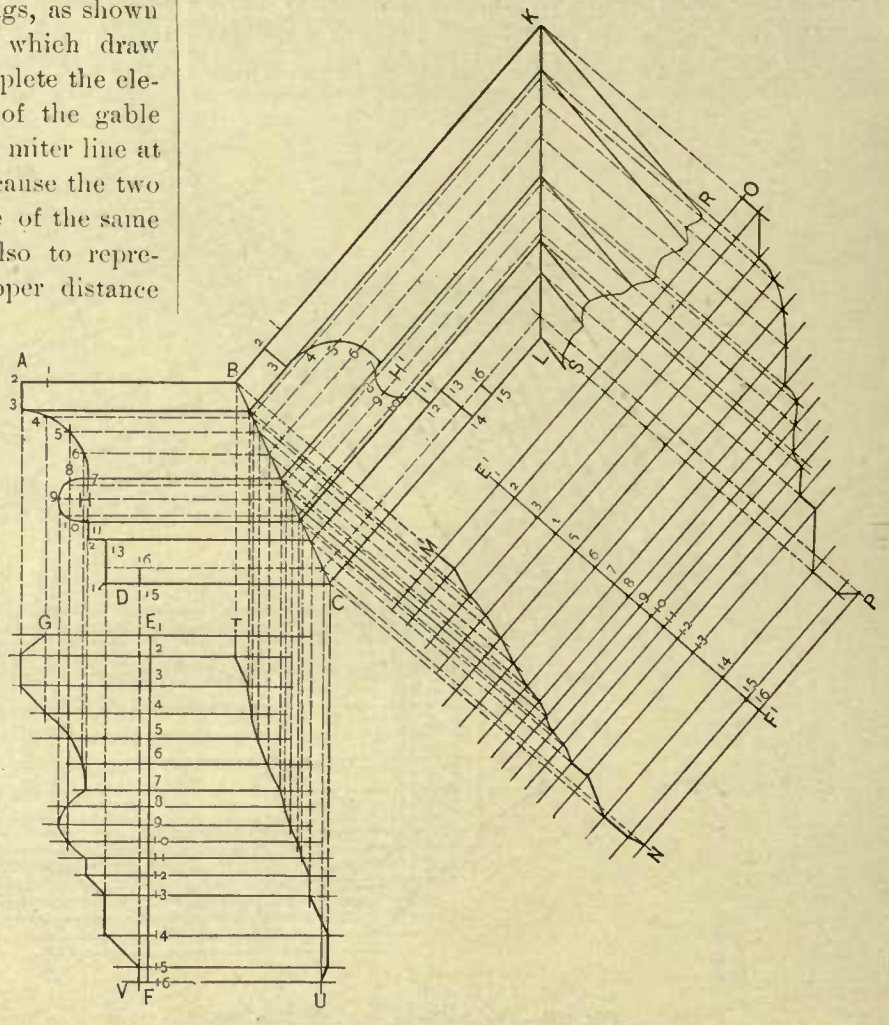


Fig. 289.—The Patterns of Simple Gable Miters.

PROBLEM 16.

The Pattern for a Pedestal of Which the Plan is an Equilateral Triangle.

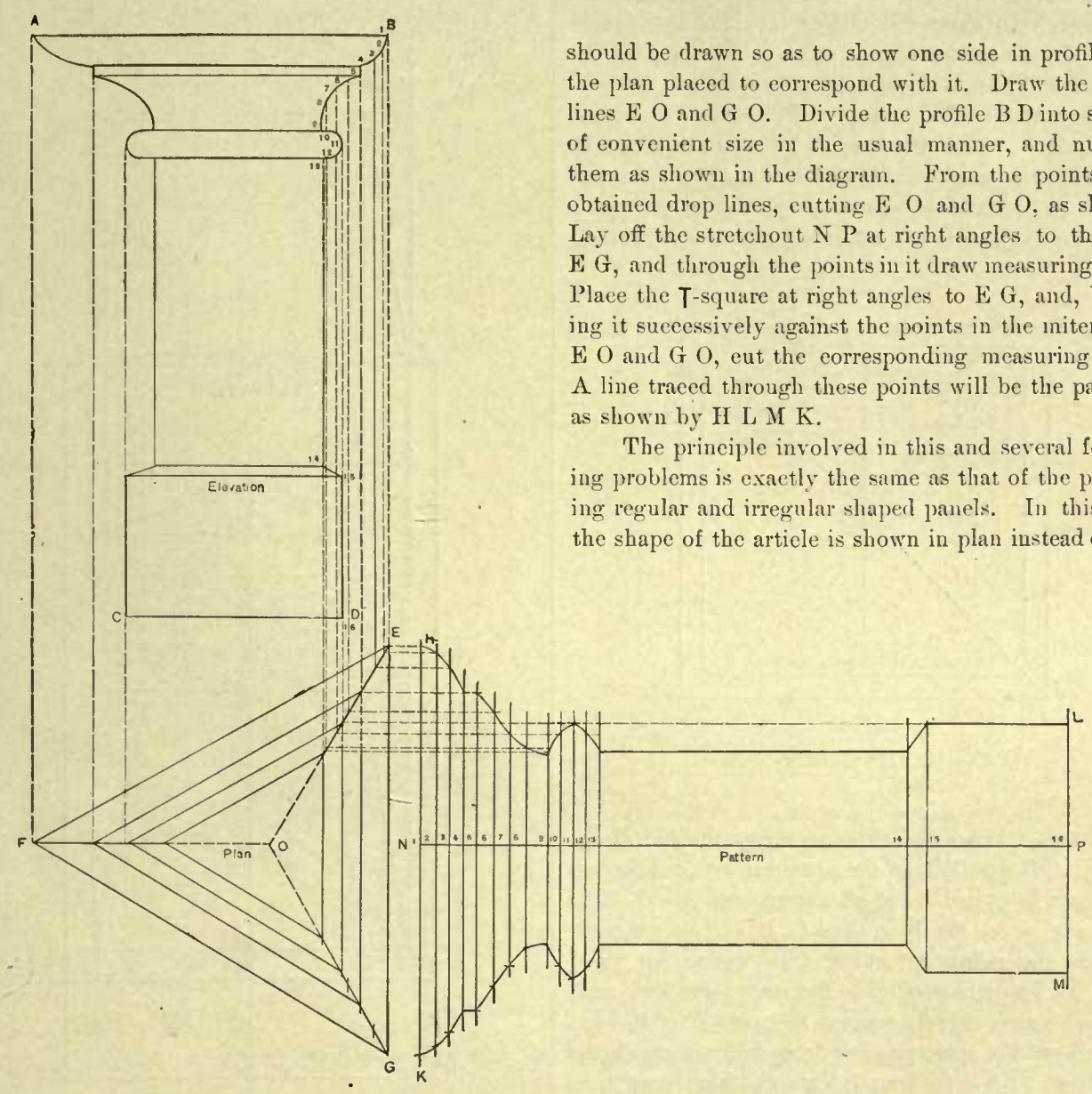


Fig. 290.—The Pattern for a Pedestal of which the Plan is an Equilateral Triangle.

Let A B D C in Fig. 290 be the elevation of a pedestal or other article of which the plan is an equilateral triangle, as shown by F E G. This elevation should be drawn so as to show one side in profile and the plan placed to correspond with it. Draw the miter lines E O and G O. Divide the profile B D into spaces of convenient size in the usual manner, and number them as shown in the diagram. From the points thus obtained drop lines, cutting E O and G O, as shown. Lay off the stretchout N P at right angles to the side E G, and through the points in it draw measuring lines. Place the T-square at right angles to E G, and, bringing it successively against the points in the miter lines E O and G O, cut the corresponding measuring lines. A line traced through these points will be the pattern, as shown by H L M K.

The principle involved in this and several following problems is exactly the same as that of the preceding regular and irregular shaped panels. In this case the shape of the article is shown in plan instead of elevation, and the profile is too large to permit of its being drawn within the plan, as were the profiles of the panel moldings in their elevations.

PROBLEM 17.

The Pattern for a Pedestal Square in Plan.

In Fig. 291, let A B D C be the elevation of a pedestal the four sides of which are alike, being in plan as shown by E H G F, Fig. 292. Since the plan is a rectangular figure the miters involved are square miters, or miters forming a joint at 90 degrees. A square miter admits of certain abbreviations, the reasons for which are explained in Problem 3, as well as in Chapter V, under the head of Parallel Forms. The abbreviated method which is here illustrated is always used. The plan is introduced only to show the shape of the article, and is not employed directly in cutting

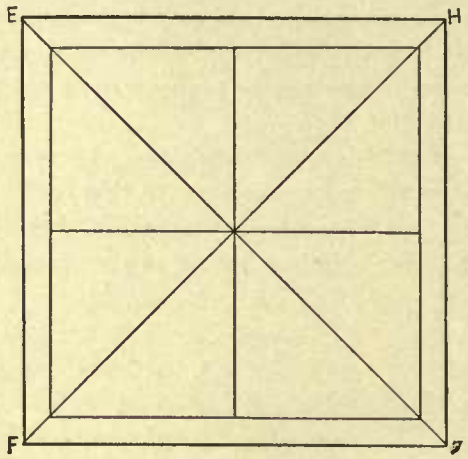


Fig. 292.—The Plan of Square Pedestal.

the pattern. Space the profiles, shown in the elevation by A C and B D, in the usual manner, numbering the points as shown. Set off a stretchout line, L R, at right angles to the base line C D of the pedestal, through the points in which draw measuring lines. Place the T-square parallel to the stretchout line, and, bringing it successively against the points in the two profiles, cut the corresponding lines drawn through the stretchout. A line traced through these points, as shown by L M O N K, will be the pattern of a side.

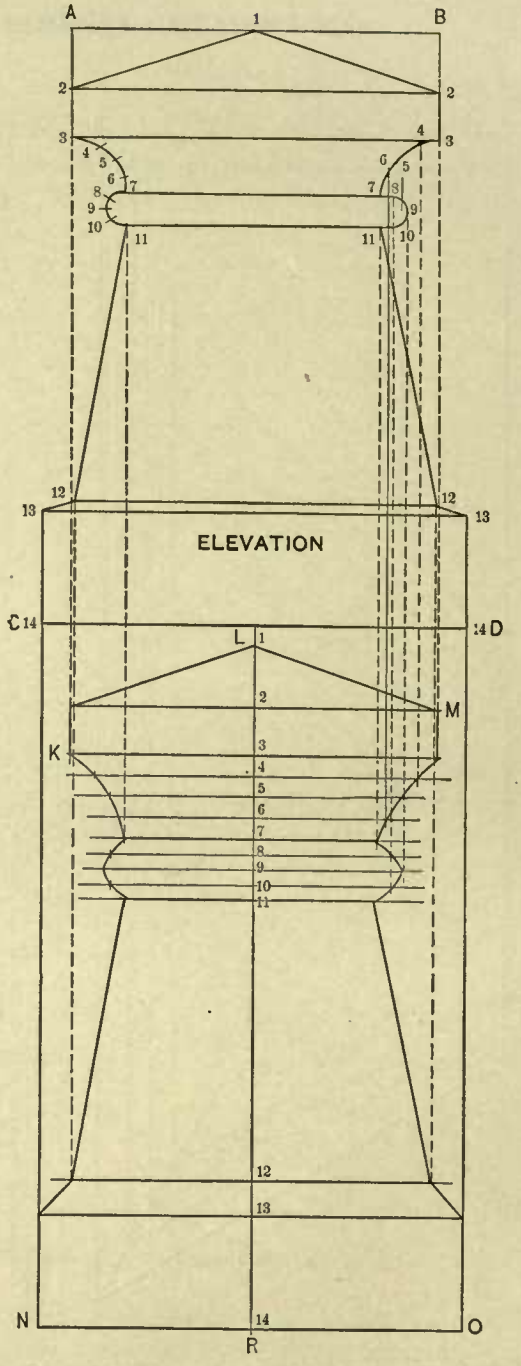


Fig. 291.—The Pattern for a Pedestal, Square in Plan.

PROBLEM 18.

The Patterns for a Vase, the Plan of Which is a Pentagon.

In Fig. 293, let S C K T be the elevation of a vase, the plan of which is a pentagon, as shown O C' C' R P. The elevation must be drawn in such a manner that one of the sides will be shown in profile. Draw the plan in line and in correspondence with it. Divide the profile into spaces of convenient size in the

usual manner and number them. Draw the miter lines C' H' and C² H² in the plan, and, bringing the T-square successively against the points in the profile, drop lines across these miter lines, as shown by the dotted lines in the engraving. Lay off the stretchout M N at right angles to the piece in the plan which

the ease of a complicated profile, or one of many different members, to drop all the points across one section of the plan C' H' H² C² would result in confusion. Therefore it is customary, in practice, to treat the pattern in sections, describing each of the several pieces of which it is composed independently of the

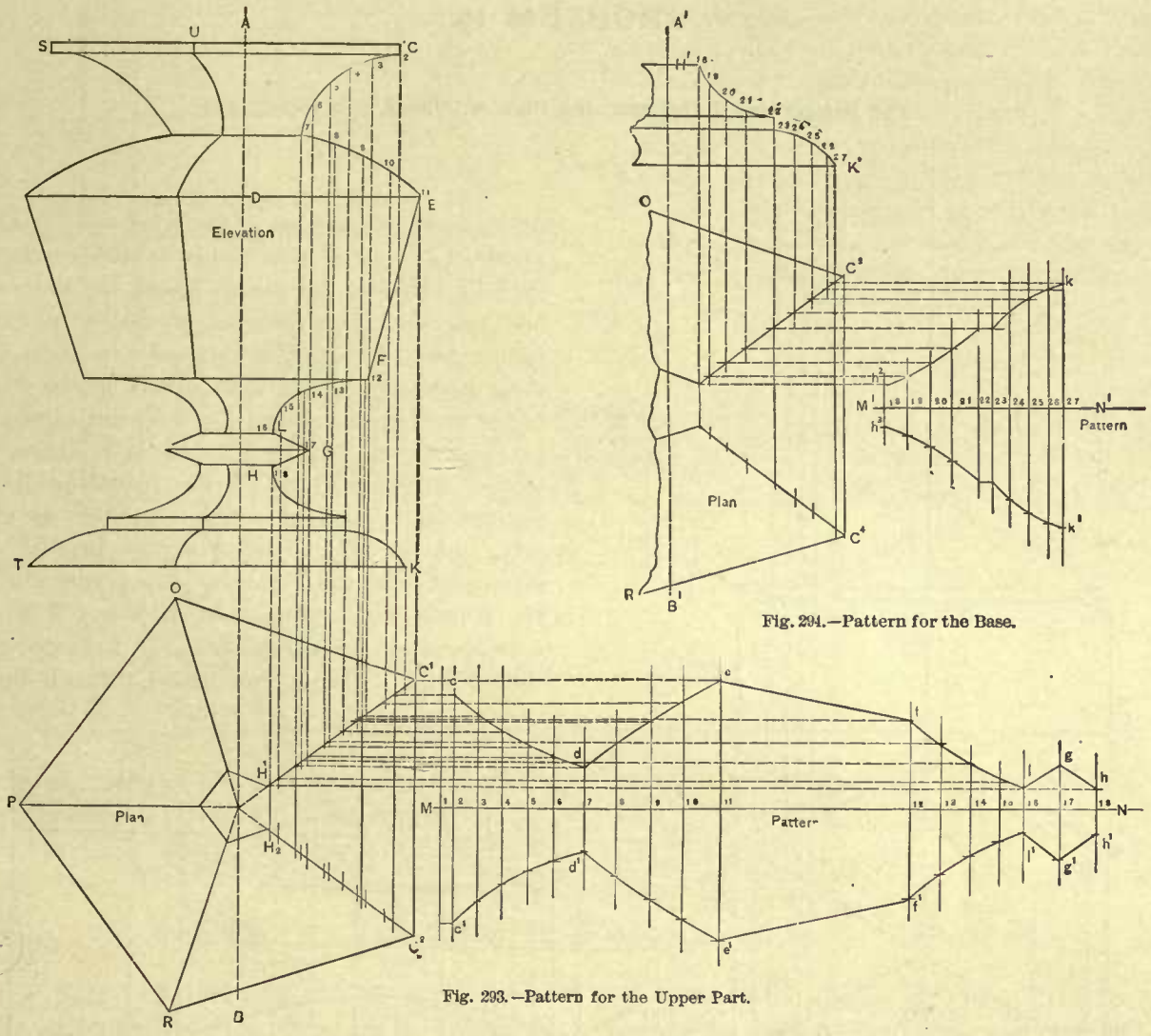


Fig. 294.—Pattern for the Base.

Fig. 293.—Pattern for the Upper Part.

The Patterns for a Vase, the Plan of which is a Pentagon.

corresponds to the side shown in profile in the elevation. Through the points in it draw the usual measuring lines. Place the T-square parallel to the stretchout line, and, bringing it against the several points in the miter lines which were dropped from the elevation upon them, cut the corresponding measuring lines drawn through the stretchout. A line traced through the points thus obtained will describe the pattern. In

others. In the illustration given the pattern has been divided at the point H, the upper portion being developed from the profile and plan, as above, while the lower part is redrawn in connection with a section of the plan, as shown in Fig. 294. Corresponding letters in each of the views represent the same parts, so that the reader will have no trouble in perceiving just what has been done. Instead of redrawing a por-

tion of the elevation and plan, as has been done in this case, sometimes it is considered best to work from one profile rather than to redraw a portion of it, as that always results in more or less inaccuracy. Therefore, after using the plan and describing a part of the pattern, as shown in the operation explained above, a piece of clean paper is pinned on the board, covering this plan and pattern, upon which a duplicate plan is drawn, from which the second section of the pattern is obtained. Great care, however, is necessary in redrawing portions of the plan to insure accuracy.

PROBLEM 19.

The Pattern for a Pedestal, the Plan of Which is a Hexagon.

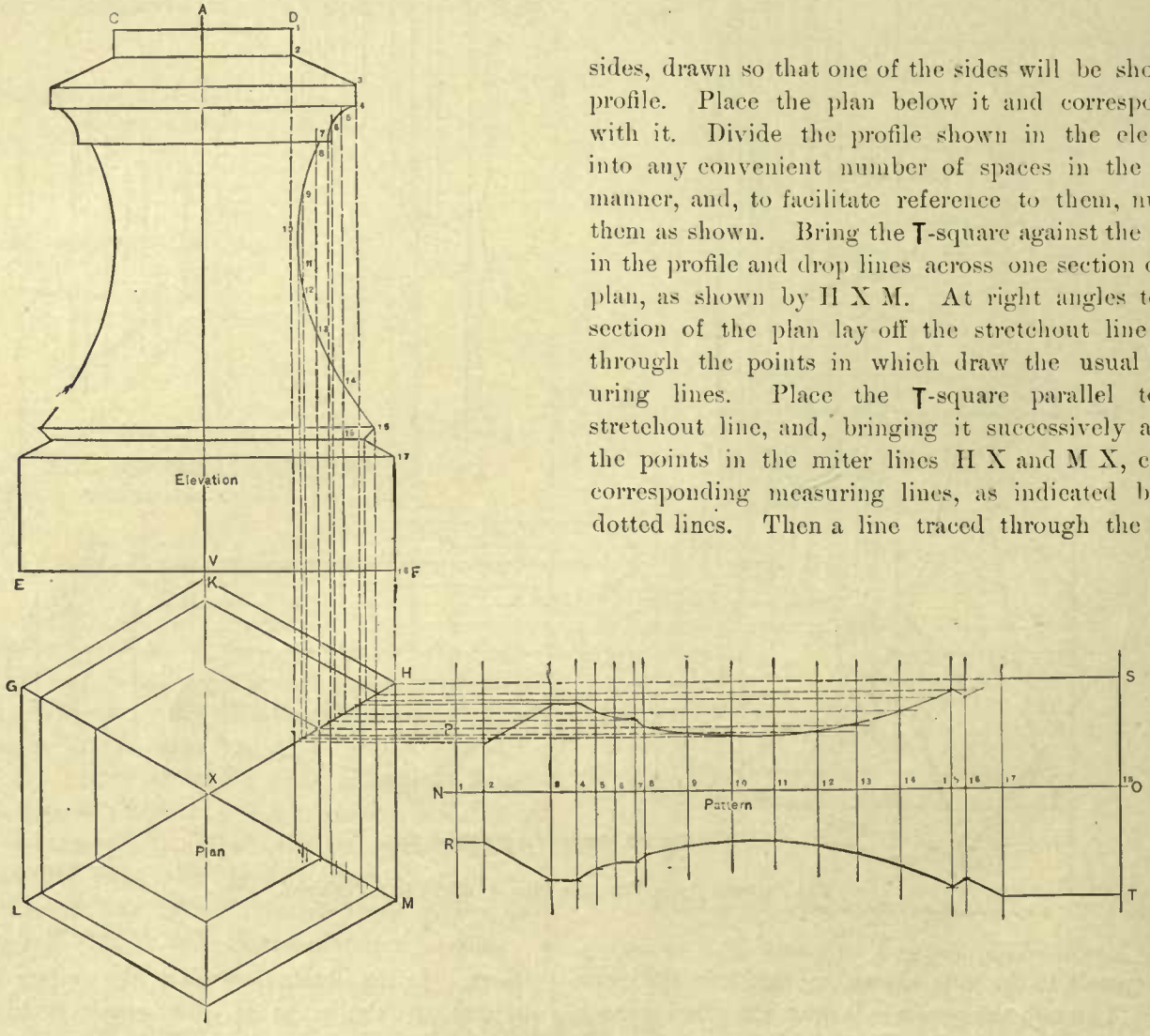


Fig. 295.—The Pattern for a Pedestal, the Plan of which is a Hexagon.

In Fig. 295, let C D F E be the elevation of a pedestal which it is desired to construct of six equal sides, drawn so that one of the sides will be shown in profile. Place the plan below it and corresponding with it. Divide the profile shown in the elevation into any convenient number of spaces in the usual manner, and, to facilitate reference to them, number them as shown. Bring the T-square against the points in the profile and drop lines across one section of the plan, as shown by H X M. At right angles to this section of the plan lay off the stretchout line N O, through the points in which draw the usual measuring lines. Place the T-square parallel to the stretchout line, and, bringing it successively against the points in the miter lines H X and M X, cut the corresponding measuring lines, as indicated by the dotted lines. Then a line traced through the points thus obtained will be the required pattern, as shown by P S T R.

PROBLEM 20.

The Pattern for a Vase, the Plan of Which is a Heptagon.

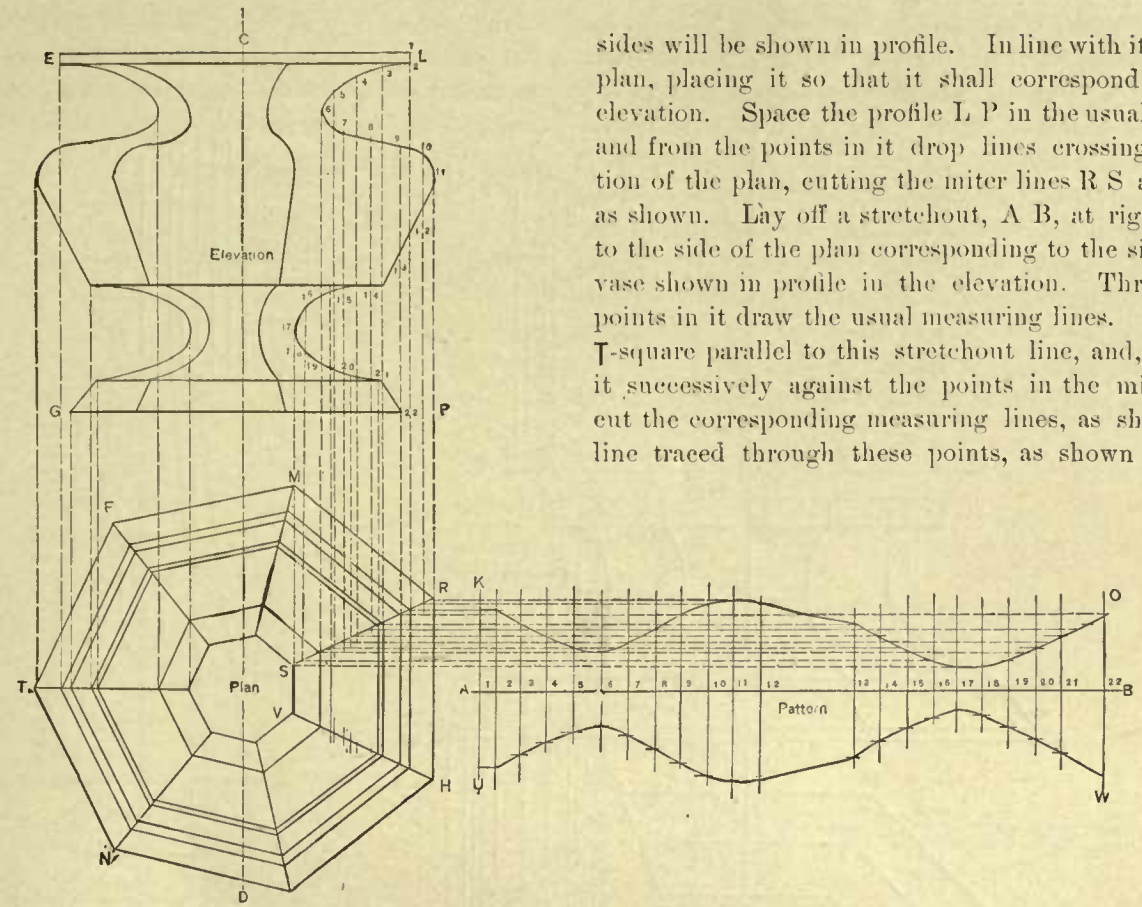


Fig. 296.—The Pattern for a Vase, the Plan of which is a Heptagon.

In Fig. 296, let E L P G be the elevation of the vase, constructed in such a manner that one of its sides will be shown in profile. In line with it draw the plan, placing it so that it shall correspond with the elevation. Space the profile L P in the usual manner, and from the points in it drop lines crossing one section of the plan, cutting the miter lines R S and H V, as shown. Lay off a stretchout, A B, at right angles to the side of the plan corresponding to the side of the vase shown in profile in the elevation. Through the points in it draw the usual measuring lines. Place the T-square parallel to this stretchout line, and, bringing it successively against the points in the miter lines, cut the corresponding measuring lines, as shown. A line traced through these points, as shown by K O W U, will be the pattern of one of the sides of the vase.

PROBLEM 21.

The Patterns for an Octagonal Pedestal.

Let K H G W L in Fig. 297 be the elevation of a pedestal octagon in plan, of which the pattern of a section is required. This elevation should be drawn in such a manner that one side of it will appear in profile. Place the plan so as to correspond in all respects with it. Divide the profile G W, from which the plan of the side desired is projected, in the usual manner, and from the points in it drop points upon each of the miter lines F T and P U in the plan. Lay off a stretchout, B E, at right angles to the side of the plan corresponding to the side of the article shown in profile in the elevation, and through the points in it draw the usual measuring lines. Place the T-square parallel to the stretchout line, and, bringing it successively against the points dropped upon the miter lines from the elevation, cut the corresponding measuring lines. A line traced through the points thus obtained will describe the pattern of one of the sides of which the article is composed. In cases where the profile is complicated, consisting of many members, and where it is very long, confusion will arise if all the points are dropped across one section of the plan, as above described. It is also quite desirable in many cases to construct the pattern in several pieces. In

such cases methods which are described in connection with Problem 18 may be used with advantage. In the present case the pattern is constructed of two pieces, being divided at the point 8 of the profile. The lower part of the pattern is cut from the plan drawn below the elevation, while the upper part of the pattern is cut by means of a part of the plan redrawn above the elevation, thus allowing the use of the same profile for both. The same letters refer to similar parts, so that the reader will have no difficulty in tracing out the relationship between the different views.

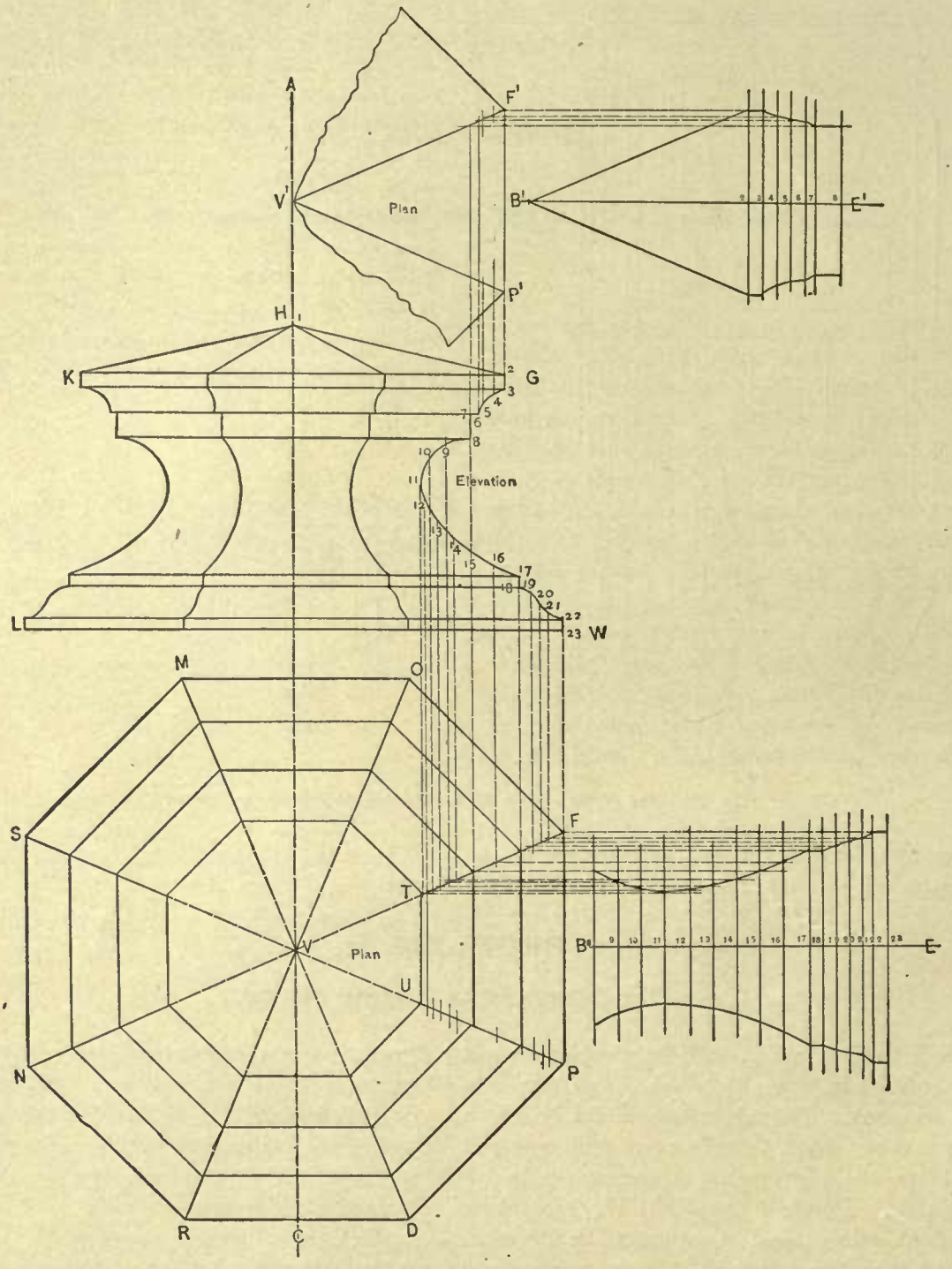


Fig. 297.—The Patterns for an Octagonal Pedestal.

PROBLEM 22.

The Patterns for a Newel Post, the Plan of Which is a Decagon.

In Fig. 298, let W U S P O R T V be the elevation of a newel post which is required to be constructed in ten parts. Draw the plan below the elevation, as shown. The elevation must show one of the sections or sides in profile, and the plan must be placed to correspond with the elevation. Space the molded parts of the profile in the usual manner, and from the points in them drop lines crossing the corresponding section of the plan, as shown by G X H, and cutting the two miter lines G X and H X. Lay off the stretchout line C D at right angles to G H, and through it draw the customary measuring lines. Place the T-square parallel to the stretchout, and, bringing it against the several points in the miter lines G X and H X, cut the corresponding measuring lines. A line traced through the points thus obtained will describe the pattern. In order to avoid confusion of lines, which would result from dropping points from the entire profile across one section of the plan, a duplicate of the cap A' W' is drawn in Fig. 299 in connection with a section of the plan, as shown by G' X' H', which are employed in precisely the same manner as above described, thus completing the pattern in two pieces, the joint being formed at the point numbered 11 of the profile and the stretchout.

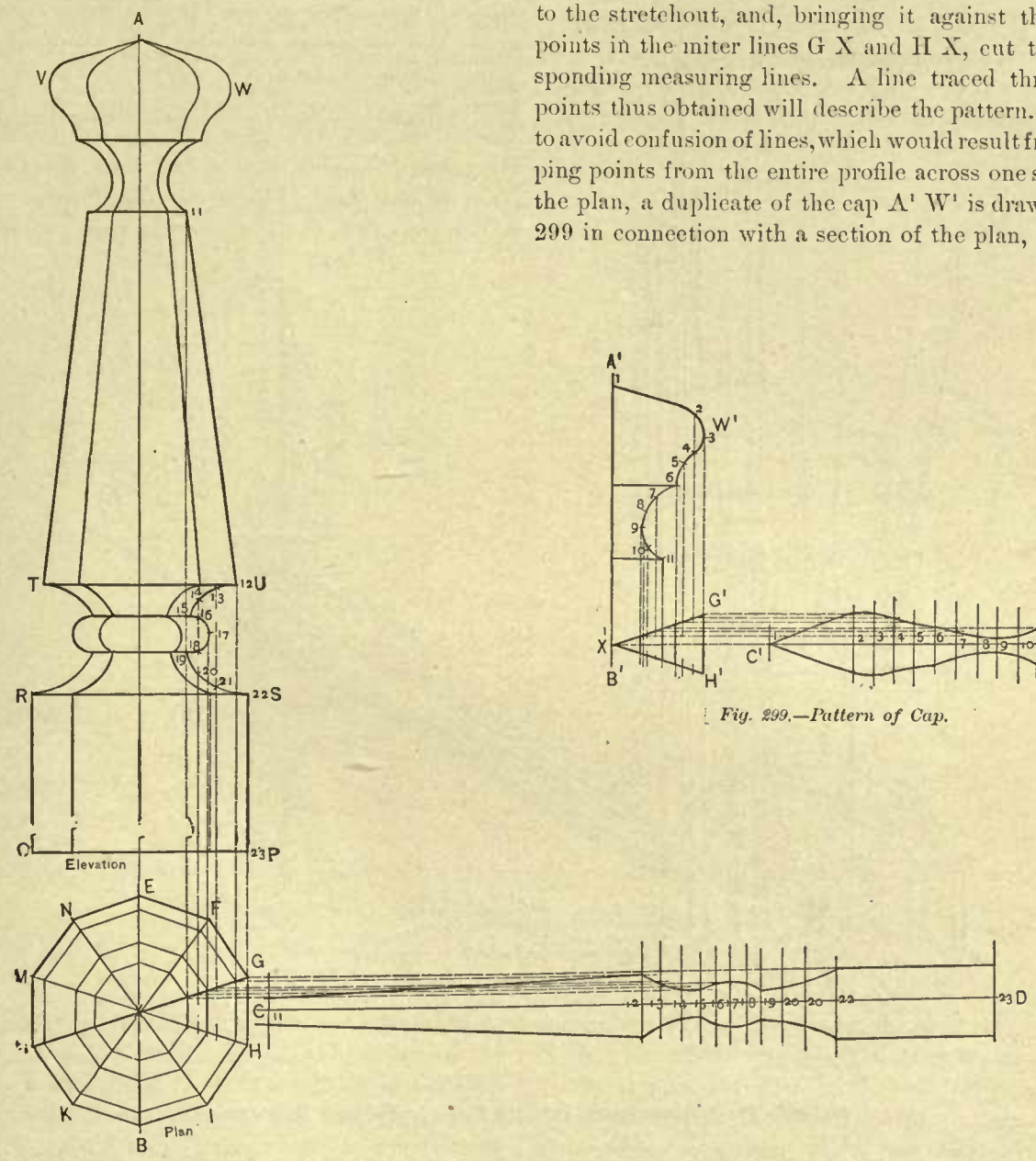


Fig. 298.—The Patterns for a Newel Post, the Plan of which is a Decagon.

Fig. 299.—Pattern of Cap.

PROBLEM 23.

The Patterns for an Urn, the Plan of Which is a Dodecagon.

In Fig. 300, let X A G H be the elevation of an urn to be constructed in twelve pieces. The elevation must be drawn so as to show one side in profile. Construct the plan, as shown, to correspond with it and draw the miter lines. Divide the profile A S G into spaces in the usual manner, and from the points thus obtained drop lines across one section, N X O, of the plan. Lay off the stretchout C D at right angles to the side N O of the plan. Place the T-square parallel to the stretchout, and, bringing it successively against the several points in the miter lines N X and O X, cut the corresponding measuring lines. A line traced through the points thus obtained will describe the pattern sought. In this illustration is shown a method sometimes resorted to by pattern cutters to avoid the confusion resulting from dropping all the points across one section of the plan. The points from 13 to 20 inclusive are dropped upon the line O X. The stretchout C D is drawn in exactly the middle of the pattern—that is, it is drawn from X, the central point of the plan. Points are transferred by the T-square from O X to the measuring lines on one side of the stretchout, the points on the other side being obtained by duplicating distances from C D on the several lines. The points 1 to 13 are dropped on N X only. The stretchout E F is laid off at right angles to the side M N from the point X, and, the T-square being set parallel to E F, the points are transferred to the

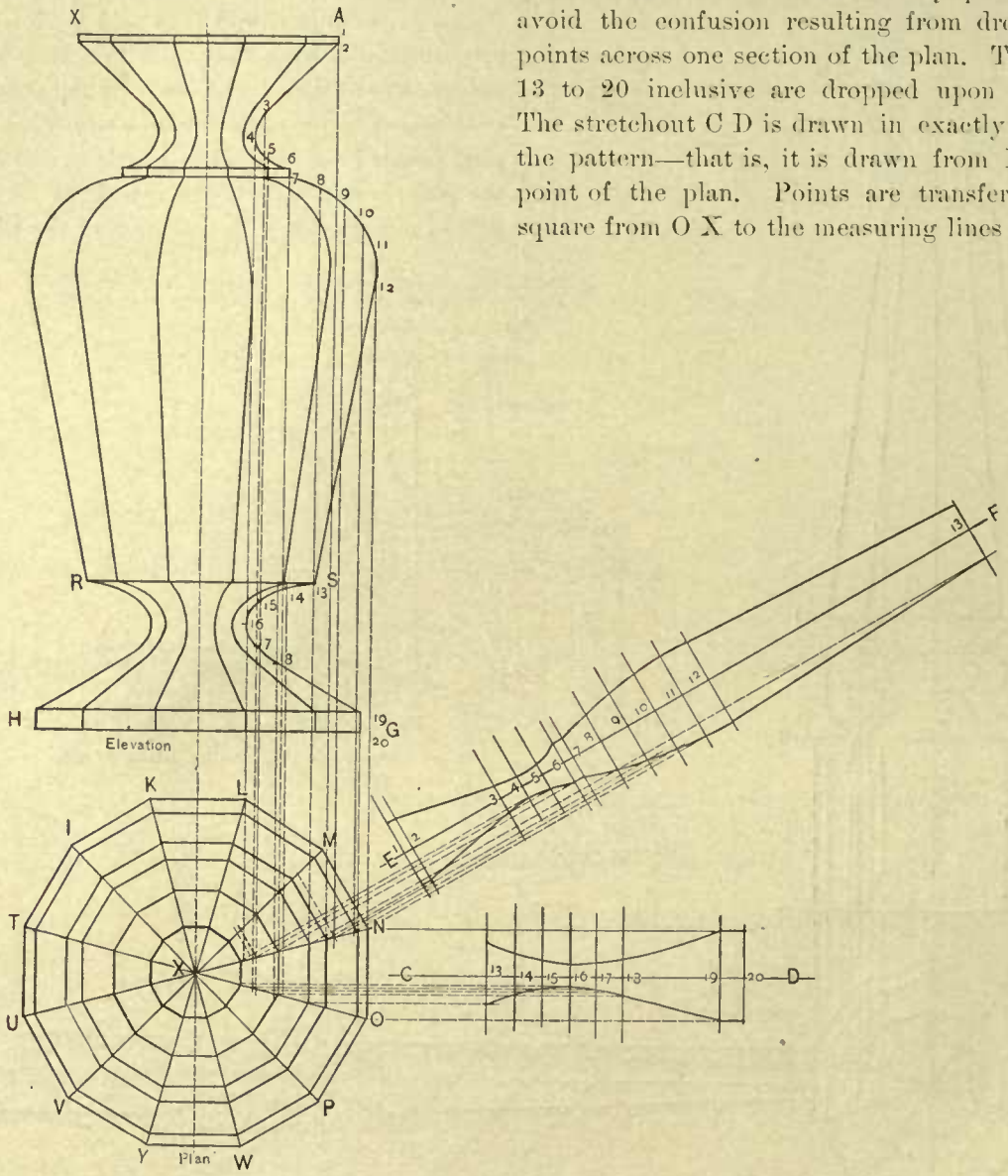


Fig. 300.—The Patterns for an Urn, the Plan of which is a Dodecagon.

measuring lines on one side of E F, while the distances on the opposite side are set off by measurement, as described in the first instance. This plan will be found advantageous in complicated and very extended profiles.

PROBLEM 24.

The Pattern for a Drop Upon the Face of a Bracket.

In Figs. 301 and 302, methods of obtaining the return strip fitting around a drop and mitering against the face of a bracket are shown. Similar letters in the two figures represent similar parts, and the following demonstration may be considered as applying to both. Let A B D C be the elevation of a part of the face of the bracket, and H K L a portion of the side, showing the connection between the side strip of the drop E F G and the face of the bracket. To state the case simply, F G is the profile and N M the miter line, because N M is the outline of the surface against which the side strip miters. Then, following the rule, divide F G into any convenient number of parts in the usual manner, as shown by the small figures. Produce H K, as shown by O P, and on O P lay off a stretchout, through the points in which draw the usual measuring lines. From the points in the profile F G carry lines in the direction of the molding—that is, parallel to K M—intersecting the face of the bracket N M. Reverse the T-square, placing the blade parallel to the stretchout line O P, and, bringing it successively against the points in N M, cut the corresponding measuring lines, as indicated by the dotted lines. Then a line traced through these several points of intersection, as shown by O R P, will be the pattern of the strip fitting around E F G and mitering against the irregular surface N M of the bracket face.

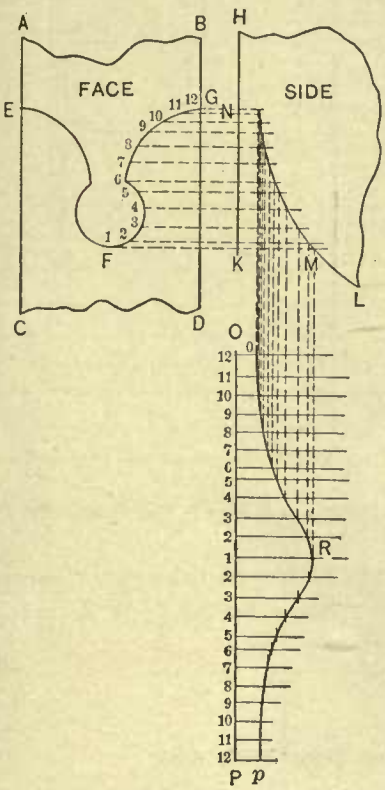


Fig. 301.

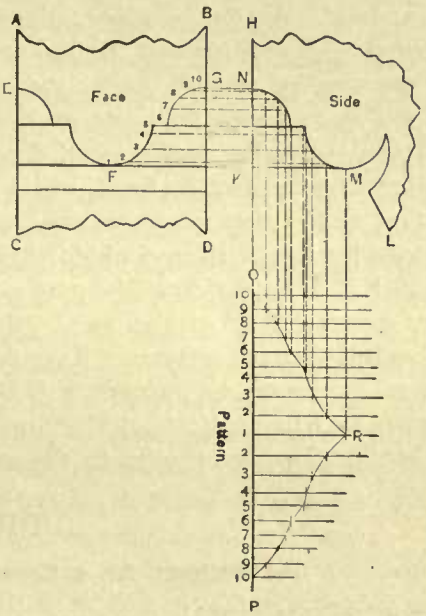


Fig. 302.

The Pattern for a Drop upon the Face of a Bracket.

PROBLEM 25.

The Pattern of a Boss Fitting Over a Miter in a Molding.

Let A B C in Fig. 303 be the part elevation of a pediment, as in a cornice or window cap, over the miter and against the molding and fascia in which a boss, F K G H, is required to be fitted, all as shown by N O E D of the side view.

The outline F K G H of the boss is to be considered as the profile of a molding running in the direction shown by D E in the side view, and mitering against the surface of the cornice shown by N O E. For the patterns proceed as follows: Divide so much of the profile of the boss K F H G as comes against the cornice, shown from K to F, into any convenient number of parts, and from these points draw lines parallel to D E—that is, to the direction of the molding under consideration—until they intersect the miter line N O E, which in this case is the profile of the cornice molding. As the boss is so placed over the angle in the cornice molding that the distance from K to F is the same as that from K to G, the part of the boss K G will be an exact duplicate of K F and may be duplicated from the pattern of K F without another side view drawn especially for it, which would have to be done if the boss was otherwise placed. Therefore, extend the line N D upon which to lay off a stretchout of K F H G, dividing the portion K' F' into the spaces shown at K F of the profile, through which draw the usual measuring lines. Make the portion F' G' equal in length to the part F H G and, lastly, the portion G' K² a duplicate of F' K' reversed, as shown. Place the T-square parallel to the stretchout line K' K², and, bringing it against the several points in N O, cut corresponding measuring lines, as

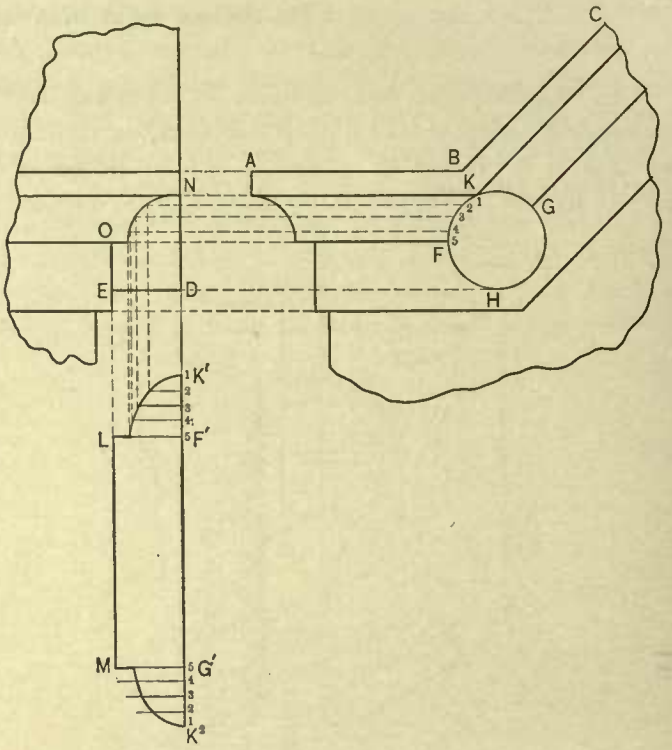


Fig. 303.—The Pattern of a Boss Fitting Over a Miter in a Molding.

shown. Then lines traced through these points of intersection, as shown by K' L M K², will be the required pattern.

PROBLEM 26.

The Patterns for a Keystone Having a Molded Face With Sink.

In Fig. 304, let E A B F be the front elevation of a keystone, as for a window cap, of which K L M P S R is a sectional view, giving the profile of the molding M N O P, over which it is required to fit. The sink in the face extends throughout its entire length, and is shown by G H D C, its depth being shown by the line K T of the section. E F H G and A B D C thus become moldings, of which E A and F B are the parallel lines, E F, G H, C D and A B the miter lines, and K R the profile. Likewise C G H D becomes a molding, of which G H and C D are the miter lines and K T the profile. Therefore, to obtain the pattern of the face pieces, divide the profile of the face K R into any convenient number of spaces, and from the points thus obtained carry lines across the face of the keystone, as shown. At right angles to the top of the keystone lay off a stretchout of K R, as shown by K² R', through which draw the usual measuring lines. Placing the T-square parallel to the stretchout line, and bringing it successively against the points in the lines C D and A B bounding the face strip, cut the corresponding measuring lines. Then a line traced through these points, as shown by C³ A² B² D², will be the pattern for this part.

In developing the pattern for the sink the usual method would be to divide K T into equal spaces, carrying lines across the face, and thence into the stretchout; but since this would result in confusion of

lines, the same points as were established in K R have been used, which are quite as convenient as the others mentioned, save that the points in K T must be obtained from the points in K R, by carrying lines back to K T, as shown, and in laying off the stretchout each individual space must be measured by the dividers.

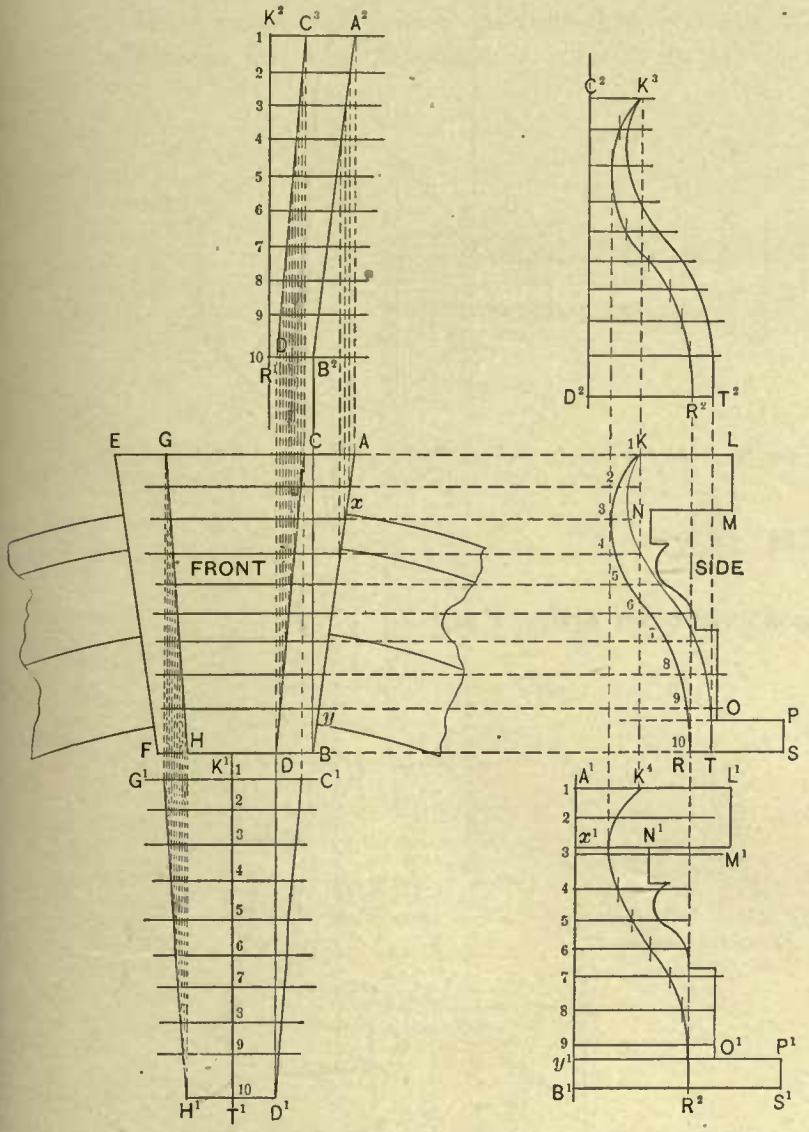


Fig. 304.—The Patterns for a Keystone Having a Molded Face with Sink.

At right angles to the line H D of the keystone lay off a stretchout of K T, as shown by K' T', through the points in which draw the usual measuring lines. Place the T-square at right angles to the lines across the face of the keystone, and, bringing it successively against the points in the lines G H and C D, forming the sides of the sink, cut the corresponding measuring lines drawn through K' T'. Then lines traced through these points, as indicated by G' H' and C' D', will form the pattern of the required sink piece. For the pattern of the piece forming the sides of the sink in the face of the keystone, K R T becomes the elevation of a molding running in the direction of R T, of which K R and K T are the miter lines and C D the profile. Hence, at any convenient place above or below the sectional view, lay off the stretchout of the line C D, as determined by the lines drawn across it in the first operation, all as indicated by C^2 D^2. Through the points in C^2 D^2 draw measuring lines in the usual manner. The next operation, in course, would be to drop lines from the points in the profile to the miter lines; but as this has already been done by the lines of the first operation, it is only necessary to place the T-square at right angles to the measuring lines, and bring it successively against the several points in the lines K R and K T, and cut the corresponding measuring lines, as shown. Then a line traced through these points, as indicated by K^2 R^2 and K^2 T^2, will be the pattern of the piece required.

For the side of the keystone, K L S R becomes the face of a molding, of which A B is the profile and K R the miter line at one side, and L M and P S the miter lines at the other. From this point forward the problem is, in principle, the same as Problem 10. For convenience, and to avoid confusion, it is best to again make use of the same set of lines instituted in the first part of the demonstration. Therefore, lay off the stretchout A' B' equal to A B, putting into it all the points occurring in A B, through which draw measuring lines in the usual manner. Place the T-square at right angles to these measuring lines, and, bringing it successively against the points in the line K R, and likewise against L M and P S of the back, cut corresponding measuring lines, as shown. Then a line traced through these points of intersection, as shown by N' M' L' K^4 R^2 S' P' O', will be the outline of the required pattern, with the exception of that part lying between N' and O', which make a duplicate of N O. By examination of the points in A' B' and the lines drawn through the same and making comparison with the points in A B, it will be seen that in order to locate accurately the position of the profile of the window cap molding M N O P, two additional points, as shown by x' and y', have been introduced, corresponding to x and y, the points of intersection between the extreme lines of the cap molding itself and the side of the keystone A B, as shown in the elevation by the curved lines of that molding. In practice it is frequently necessary to introduce extra points in operations of this character.

PROBLEM 27.

The Pattern of a Square Shaft to Fit Against a Sphere.

In Fig. 305, let H A A' K be the elevation of a square shaft, one end of which is required to fit against the ball D F E. Draw the center line F L, upon which locate the center of the ball G. Continue the sides of the shaft across the line of the circumference of the ball indefinitely. From the points of intersection between the sides of the shaft and the circumference of the ball, A or A', draw a line at right angles to the sides of the shaft, across the ball, cutting the center line, as shown at B. Set the dividers to G B as radius, and from G as center, describe the arc C C', cutting the sides in the points C and C'. Then H C C' K will be the pattern of one side of a square shaft to fit against the given ball.

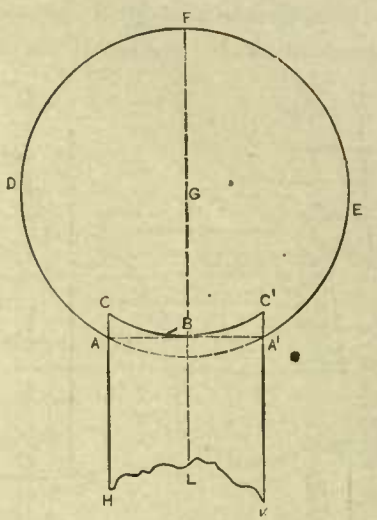


Fig. 305.—The Pattern of a Square Shaft to Fit Against a Sphere.

PROBLEM 28.

To Describe the Pattern of an Octagon Shaft to Fit Against a Ball.

Let H F K in Fig. 306 be the given ball, of which G is the center. Let D^2 C^2 C^3 D^3 E represent a plan of the octagon shaft which is required to fit against the ball. Draw this plan in line with the center of the ball, as indicated by F E. From the angles of the plan project lines upward, cutting the circle and constituting the elevation of the shaft. From the point A or A', where the side in profile cuts the circle, draw a line at right angles to the center line of the ball F E, cutting it in the point B, as shown. Through B, from the center G by which the circle of the ball was struck, describe an arc, cutting the two lines drawn from the inner angles C^2 C^3 of the plan, as shown at C and C'. Then M C C' N will be the pattern of one side of an octagon shaft mitering against the given ball H F K. If it be desired to complete the elevation of the shaft meeting the ball, it may be done by carrying lines from C and C' horizontally until they meet the outer line of the shaft in the points D and D'. Connect C' and D', also C and D, by a curved line, the lowest point in which shall touch the horizontal line drawn through B. Then the broken line D C C' D' will be the miter line in elevation formed by the junction of the octagonal shaft with the ball.

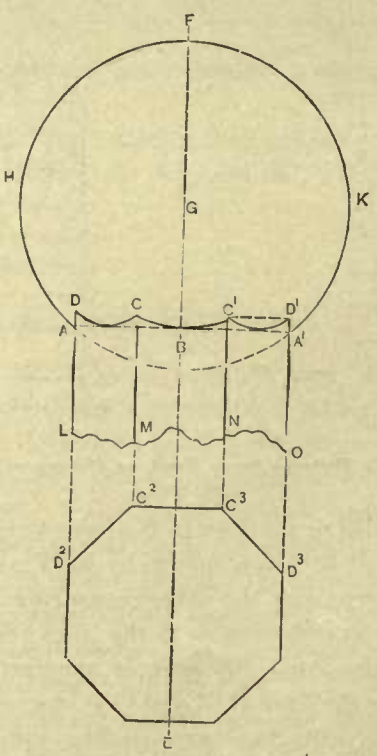


Fig. 306.—The Pattern of an Octagon Shaft to Fit Against a Ball.

PROBLEM 29.

The Patterns of an Octagonal Shaft, the Profile of Which is Curved, Fitting over the Ridge of a Roof.

In Fig. 307 is shown the elevation and plan of the shaft of a finial of the design shown in Fig. 308. The shaft is octagon throughout, and if it were designed to stand upon a level surface, the method of obtaining its patterns would be the same in all respects as that described in Problem 21. As shown by the line K *m* K, however, its lower end is designed to fit over the ridge of a roof or gable, to obtain the patterns of which proceed as follows:

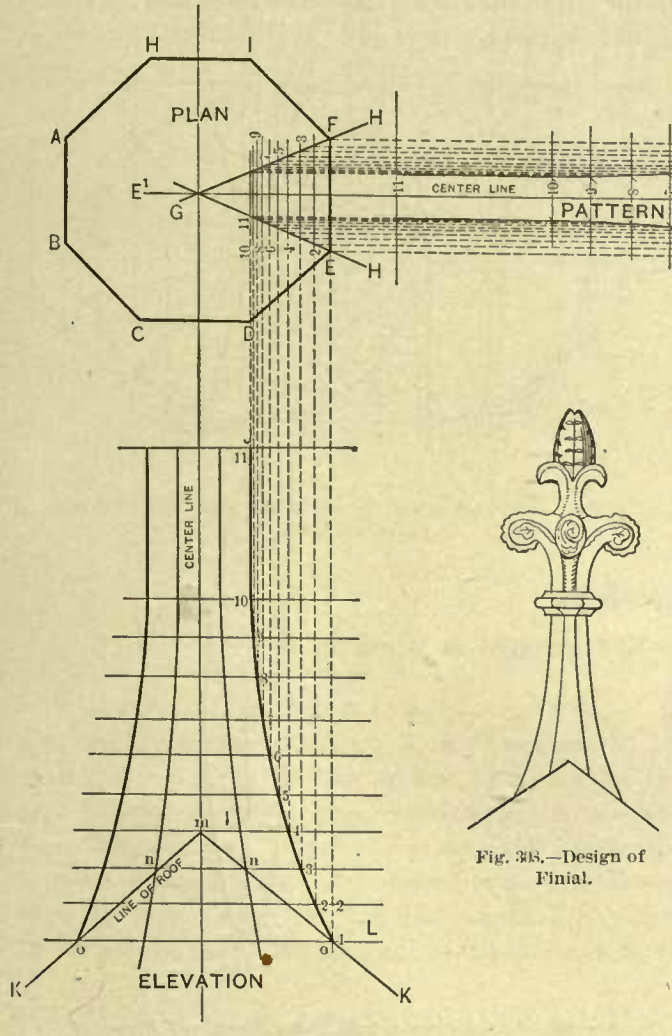


Fig. 307.—Plan, Elevation and Patterns.

The Patterns of an Octagonal Shaft, Curved in Profile, Fitting over a Ridge.

Fig. 308.—Design of Finial.

Construct a plan of the shaft at its largest section, as shown by A B C D E F, from the center of which draw miter lines, as shown by G E' and G F. Divide the profile of the shaft J L, corresponding to F G E of the plan, into any number of parts in the usual manner, and from these points carry lines vertically crossing the miter lines G E and G F. From the center G draw E' M' at right angles to E F, upon which line lay off a stretchout of the profile J L, drawing measuring lines through the points. Place the T-square parallel to the stretchout line, and, bringing it successively against the points in G E and G F, cut corresponding measuring lines, as shown, and through the points thus obtained trace lines, all as indicated in the drawing. This gives the general shape of the pattern for the sides of the shaft. By inspection of the plan and elevation together, it will be seen that to fit the shaft over the roof some of the sections composing it will require different cuts at their lower extremities. Two of the sections will be cut the same as the pattern already described. They correspond to the side marked A B and E F in the plan. Two others, indicated in the plan by C D and H I, will be cut to fit over the ridge of the roof, as shown in the elevation by *n m n*. The remaining four pieces, shown in plan by B C, D E, F I and A H, will be cut obliquely to fit against the pitch of the roof, as shown by *n o* in the elevation. For the sides C D and H I, shown in the center of the elevation, it will be seen that the line drawn from 4 touches the ridge in the point *m*, while the line drawn from 3 corresponds to the point at which the side terminates against the pitch of the roof. Therefore, in the pattern draw a line from the center of it, on the measuring line 4, to the sides of it, on the measuring line 3, all as shown by m^1 n^1 and m^1 n^1. Then these are the lines of cut in the pattern corresponding to *m n* and *m n* of the elevation. By further inspection of the elevation, it will be seen that for the remaining four sides it is necessary to make a cut in the pattern from one side, in a point corresponding to 3 of the profile, to the other, in a point corresponding to 1 of the profile, all as shown by *n o*. Taking corresponding points, therefore, in the measuring lines of the pattern, draw the lines n^1 o^1, as shown. Then the original pattern, modified by cutting upon these lines, will constitute the pattern for the four octagon sides.

PROBLEM 30.

To Construct a Ball in any Number of Pieces, of the Shape of Gores.

Draw a circle of a size corresponding to the required ball, as shown in Fig. 309, which divide, by any of the usual methods employed in the construction of polygons, into the number of parts of which it is desired to construct the ball, in this case twelve, all as shown by E, F, G, H, etc. From the center draw radial lines, R E and R F, etc., representing the joints between the gores, or otherwise the miter lines. If the polygon is inscribed, as shown in the illustration, it will be observed that the joint or miter lines will lie in the surface of the sphere and that therefore the middle of the pieces, as shown at W, C and u^1, will fall inside the surface of the sphere a greater or less distance according to the number of gores into which the sphere has been divided, and that therefore it becomes necessary to construct a section through the middle of one of the sides for use as a profile from which to obtain a stretchout. It will be well to distinguish here between absolute accuracy and something that will do practically just as well and save much labor. This profile, if made complete, would have for its width the distance W u^1, while its hight or distance through from R to a point opposite would be equal to the diameter of the circle, or twice the distance R U. As one-quarter of this section will answer every purpose, it may be constructed with sufficient accuracy as follows: Supposing R E F to be the piece under consideration, draw a line parallel to its center line R C conveniently near, as A V^1, upon which locate the points A and V by projection from C and R, as shown by the dotted lines. From the point V erect the line B V perpendicular to V^1 A, and make B V equal to the radius of the circle, or R V; then an arc of a circle cutting the points B and A will complete the section. This can be done by taking the radius R U between the points of the compasses and describing an arc from the point V^1, whose distance from V is equal to the distance u^1 U. To develop the pattern divide B A into any convenient number of equal parts, and from the divisions thus obtained carry lines across the section E R F at right angles to a line drawn through its center, and cutting its miter lines, all as shown in R E and R F. Prolong the center line R C, as shown by S T, and on it lay off a stretchout obtained from B A, through the points in which draw measuring lines in the usual manner. Place the T-square parallel to the stretchout line, and, bringing it successively against the points in the miter lines R E and R F, cut the corresponding measuring lines, as shown. A line traced through these points will give the pattern of a section. If, on laying out the plan of the ball, the polygon had been drawn about the circle, instead of inscribed, as shown in the engraving, it is quite evident that a quarter of

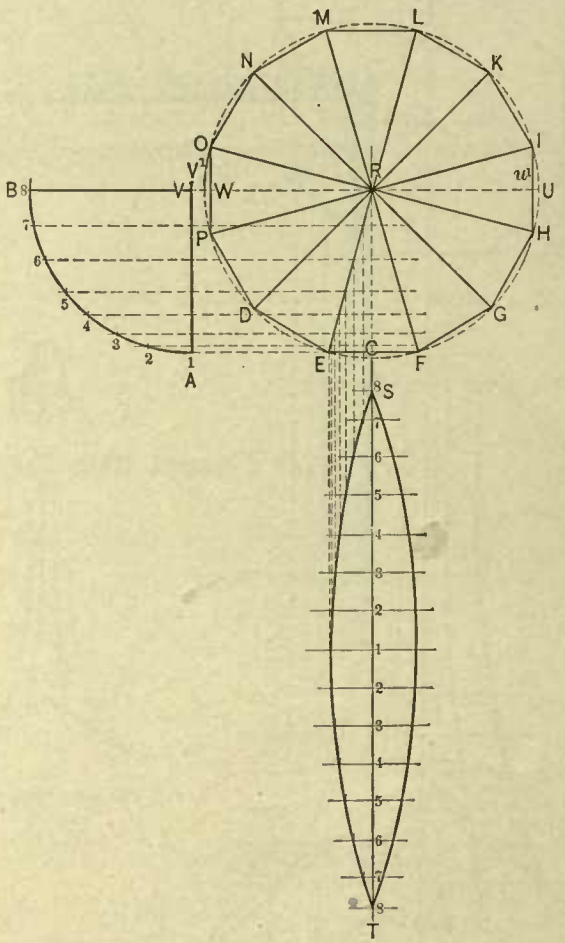


Fig. 309.—To Construct a Ball in any Number of Pieces, of the Shape of Gores.

the circle would have answered the purpose of a profile. These points, with reference to the profile, are to be observed in determining the size of the ball. In the illustration presented, the ball produced will correspond in its miter lines to the diameter of the circle laid down, while if measured on lines drawn through the center of its sections it will be smaller than the circle.

The patterns for a ball made up of zones or strips having parallel sides will be found in Section 2 of this chapter (Regular Tapering Forms).

PROBLEM 31.

The Pattern of a Round Pipe to Fit Against a Roof of One Inclination.

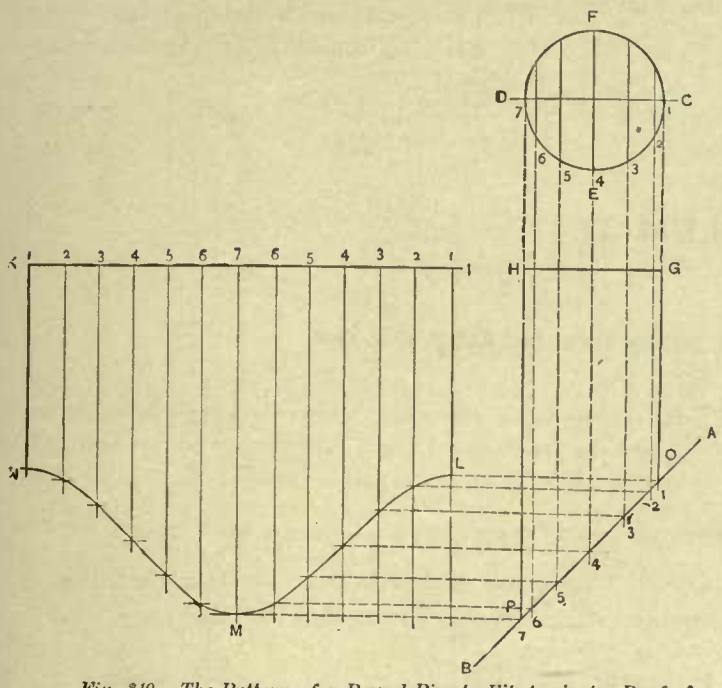


Fig. 310.—The Pattern of a Round Pipe to Fit Against a Roof of One Inclination.

In Fig. 310, let A B be the pitch of the roof and C F D E the profile of the pipe which is to miter against it. Let G O P H be the elevation of the pipe as required. Draw the profile in line with the elevation, as shown by C F D E, and divide it into any convenient number of equal parts. Lay off a stretchout in the usual manner, at right angles to and opposite the end of the pipe, as shown by I K, and draw the measuring lines. Place the T-square parallel to the sides of the pipe, and, bringing it successively against the divisions of the profile, cut the pitch line, as shown by A B. Reverse the T-square, placing it at right angles to the pipe, and, bringing it successively against the points in A B, cut the corresponding measuring lines. A line traced through the points thus obtained, as shown by L M N, will finish the pattern.

PROBLEM 32.

The Pattern of an Elliptical Pipe to Fit Against a Roof of One Inclination.

In Fig. 311, let N C D O be the elevation of an elliptical pipe fitting against a roof, represented by A B. Let E F G Q be the section or profile of the pipe. Draw the profile in convenient proximity to the elevation, as shown, and divide it into any convenient number of equal parts. Place the T-square parallel to the sides of the pipe, and, bringing it against the points in the profile, drop lines cutting the roof line A B, as shown. Opposite to the end of the pipe, and at right angles to it, lay off a stretchout, as shown by H I, and through the points in it draw measuring lines in the usual manner. Reverse the T-square, placing it at right angles to the pipe, and, bringing it successively against the points in A B, cut the corresponding

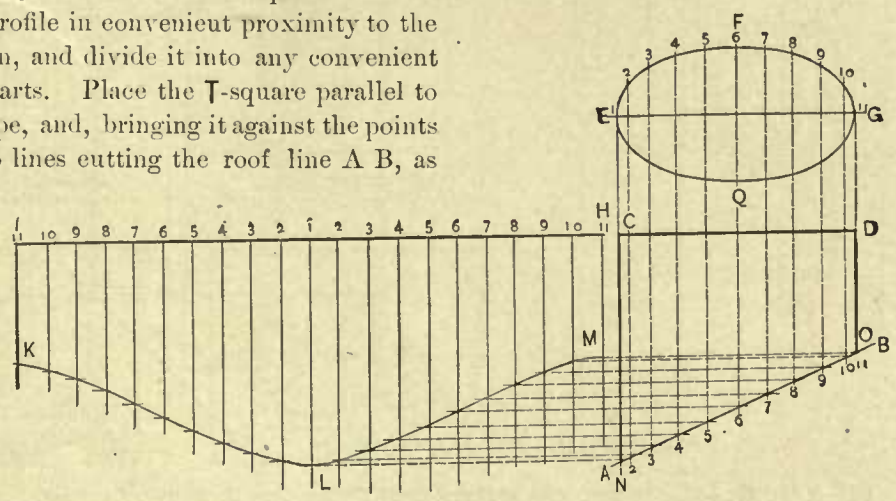


Fig. 311.—The Pattern of an Elliptical Pipe to Fit Against a Roof of One Inclination.

measuring lines, as indicated. A line traced through these points, as shown by K L M, will be the required pattern. In the illustration the long diameter of the ellipse, or E G, is shown as crossing the roof. The method of procedure would be exactly the same if the pipe were placed in the opposite position—that is, with the short diameter Q F crossing the roof. In such case the profile should be turned so that Q F is across the roof, or parallel to C D, and the elevation duly projected from it. The pipe might with equal facility be placed so that the long diameter should lie at any oblique angle desired.

PROBLEM 33.

The Pattern of an Octagon Shaft Fitting Over the Ridge of a Roof.

In Fig. 312, let A B C be the section and D H G I E the elevation of an octagon shaft mitering against a roof, represented by the lines F G and G K. Place the section in line with the elevation, as shown, and from the angles drop lines, giving T V and U W of the elevation. Drop the point G back on to the section, thus locating the points 9 and 4. Opposite the end of the shaft, and at right angles to it, draw a stretchout line, as shown by S R, and through the points in it draw measuring lines in the usual manner. Place the T-square at right angles to the shaft, and, bringing it successively against the points in the roof line formed by the intersection with it of the angle lines in the elevation, and also against the point G, representing the ridge of the roof, cut the corresponding measuring lines. Then a line traced through the points thus obtained, all as shown by P O N M L in the engraving, will be the lower end of the pattern required.

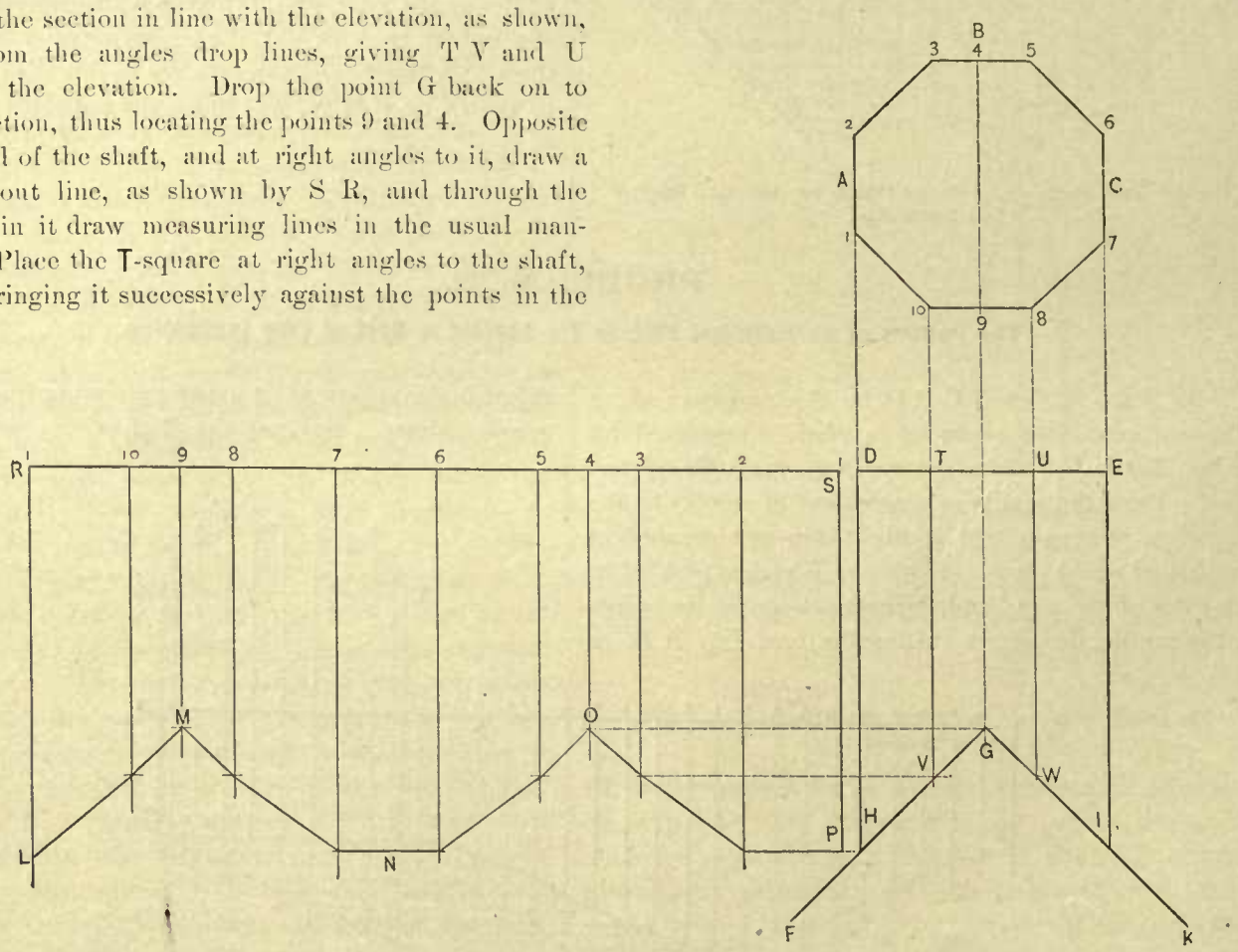


Fig. 312.—The Pattern of an Octagon Shaft Fitting Over the Ridge of a Roof.

PROBLEM 34

The Pattern of a Round Pipe to Fit Over the Ridge of a Roof.

Let A B C in Fig. 313 be a section of the roof and D S B T E an elevation of the pipe. Draw a profile of the pipe in line, as shown by F G H. Since both inclinations of the roof are to the same angle, both halves of the pattern will be the same. Therefore space off the half of the profile which miters against one slope of the roof, and lay off the stretchout of the same upon the stretchout line I K, drawn at right angles to the lines of the pipe, which may be duplicated in a reverse order for the other half, as shown. Draw measuring lines through these points in the usual manner. Place the T-square parallel to the sides of the pipe, and, bringing it against the points in the profile, cut the roof line, as shown from B to T. Reverse the T-square, placing it at right angles to the lines of the pipe, and, bringing it successively against the points dropped upon the roof line, cut the corresponding measuring lines. A line traced through the points, as shown by L M N O P, will form that end of the pattern which meets the roof.

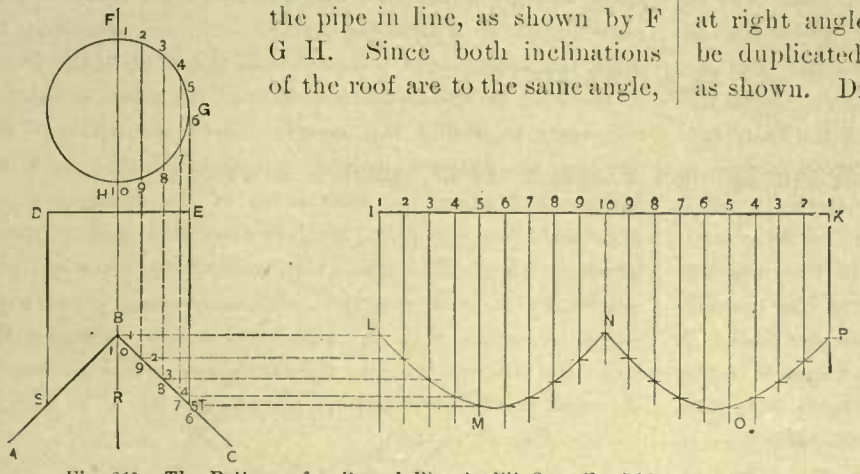


Fig. 313.—The Pattern of a Round Pipe to Fit Over the Ridge of a Roof.

PROBLEM 35

An Octagon Shaft Mitering Upon the Ridge and Hips of a Roof.

In Fig. 314 are shown the front and side elevations of a hipped roof, below which are placed plans, each turned so as to correspond with the elevation above it. Before the pattern of the shaft can be developed it will be necessary to obtain a correct elevation of its intersection with the roof. Therefore, considering the plan

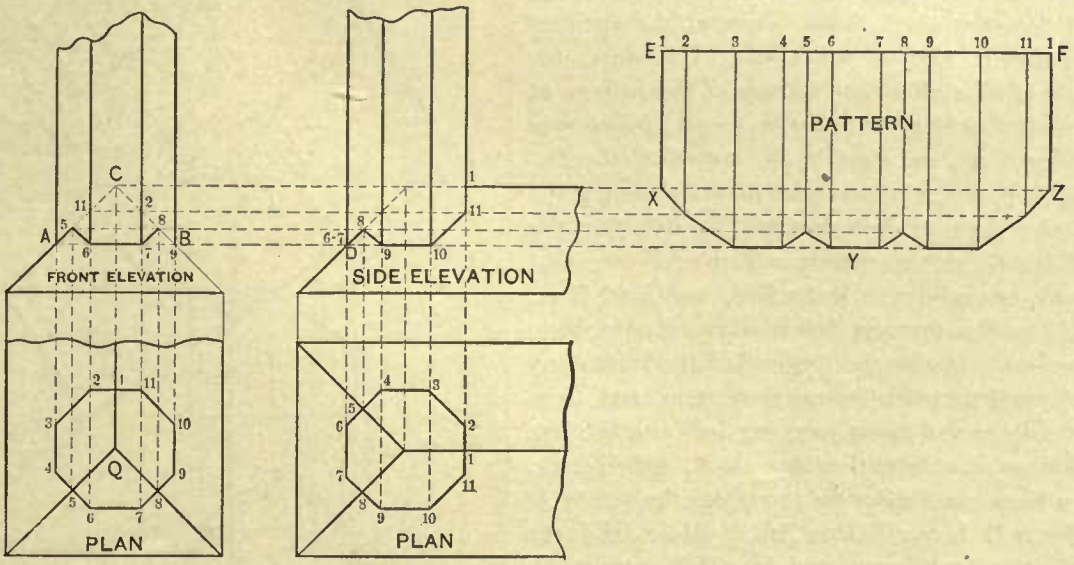


Fig. 314.—The Pattern of an Octagon Shaft Fitting Over the Ridge and Hips of a Roof.

An octagonal shaft is required to be mitered down upon this roof, so that its center line or axis shall intersect the apex of the roof C, as shown upon the plans. of the shaft as the profile of a molding, number all its points in both plans, beginning, for convenience, at the ridge of the roof, and including the points where the

oblique sides cross the hips of the roof, as shown by the small figures 1 to 11. The next step is to project lines upward into the elevations from each of these points, continuing them till they intersect the lines of the roof, as shown by the vertical dotted lines. From each of these intersections in either view lines can be projected horizontally to the other view till they intersect with lines of corresponding number. Thus the points 9 and 10 cut the line of the hip in the front elevation at the point B, which, being carried across to the side view and intersected with lines from points 9 and 10 from the plan below it, give the correct position of those points in the side view. In like manner the intersection of lines from points 6 and 7 in the side view, with the hip line at D, give the correct hight of those points in the front view. Points 5 and 8, being upon the hips, must appear in the elevations at points where the vertical lines from them cut the hip lines in the elevations. Lines connecting these points (5, 6, 7 and 8, and 8, 9, 10 and 11) will complete the elevations. In case all sides of the roof have the same pitch and the shaft is a regular octagon, all the angles of the shaft except 2 and 11 will intersect the roof at the same hight, in which case it will only be necessary to draw the front view. But should the slope of the front of the roof be different from that of the sides, it will be necessary to follow the course above described. To develop the pattern, draw any horizontal line, as E F, upon which place the stretchout of the octagon shaft obtained from the plan, as shown by the small figures, through which draw the usual measuring lines at right angles to it, and intersect the measuring lines with lines of corresponding numbers drawn horizontally from the intersections in the elevation. A line traced through these intersections, as shown by X Y Z, will be the desired pattern.

PROBLEM 36.

The Pattern of a Flange to Fit Around a Pipe and Over the Ridge of a Roof.

In Fig. 315, let A B C be the section of the roof against which the flange is to fit, and let O P S R be the elevation of the pipe required to pass through the flange. Let the flange in size be required to extend from A to C over the ridge B. Since both sides of the roof are of the same pitch, both halves of the opening from the point B will be the same. Therefore, for convenience in obtaining both halves of the pattern at one operation, the line B C may be continued across the pipe toward A', and used in place of B A, the distance from B on either line to the side O R being the same. Under these conditions it will be seen that the process of describing the pattern is identical with that in the previous problem. Make B A' equal to B A, and proceed in the manner described in the problem just referred to. Divide the profile D E F G into any number of equal parts in the usual manner, and from the points so obtained carry lines vertically to the line A' C, and thence, at right angles to it, indefinitely. Also carry lines in a similar manner from the points A' and C. Draw H L parallel to A' C. Make H I the width of the required flange, and draw I K parallel to H L. Through that part of the flange in which the center of the required opening is desired to be draw the line A² C', crossing the lines drawn from the profile. From each side of this line, on the several

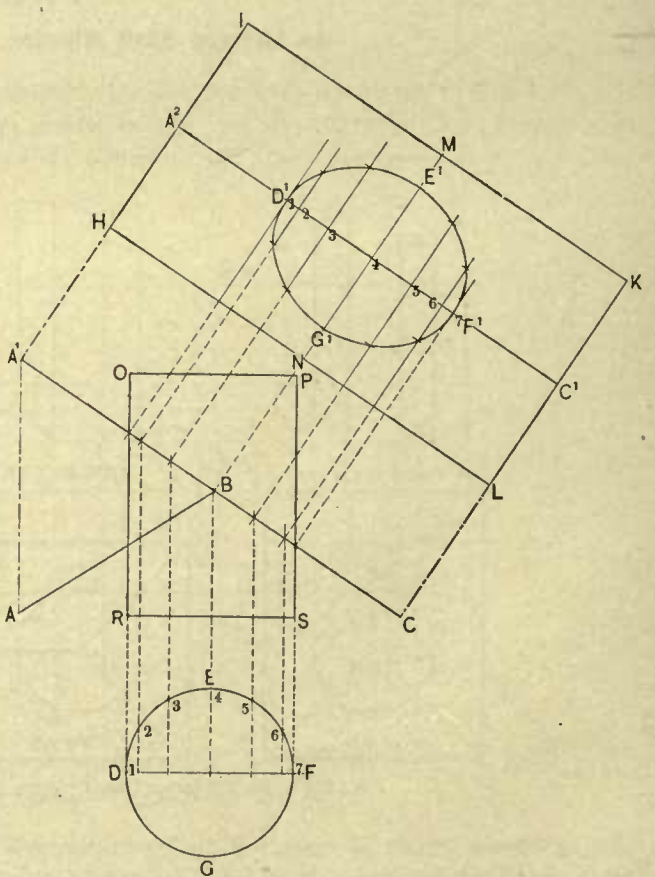


Fig. 315.—The Pattern of a Flange to Fit Around a Pipe and Over the Ridge of a Roof.

measuring lines, set off the same distance as shown upon the corresponding lines between D F and D E F, as shown. A line traced through the points thus obtained, as shown by D' E' F' G', will be the required opening to fit the pipe. Through the center, across the flange, draw the line N M, which represents the line of bend corresponding to the ridge B of the section of the roof.

PROBLEM 37.

The Pattern of a Flange to Fit Around a Pipe and Against a Roof of One Inclination.

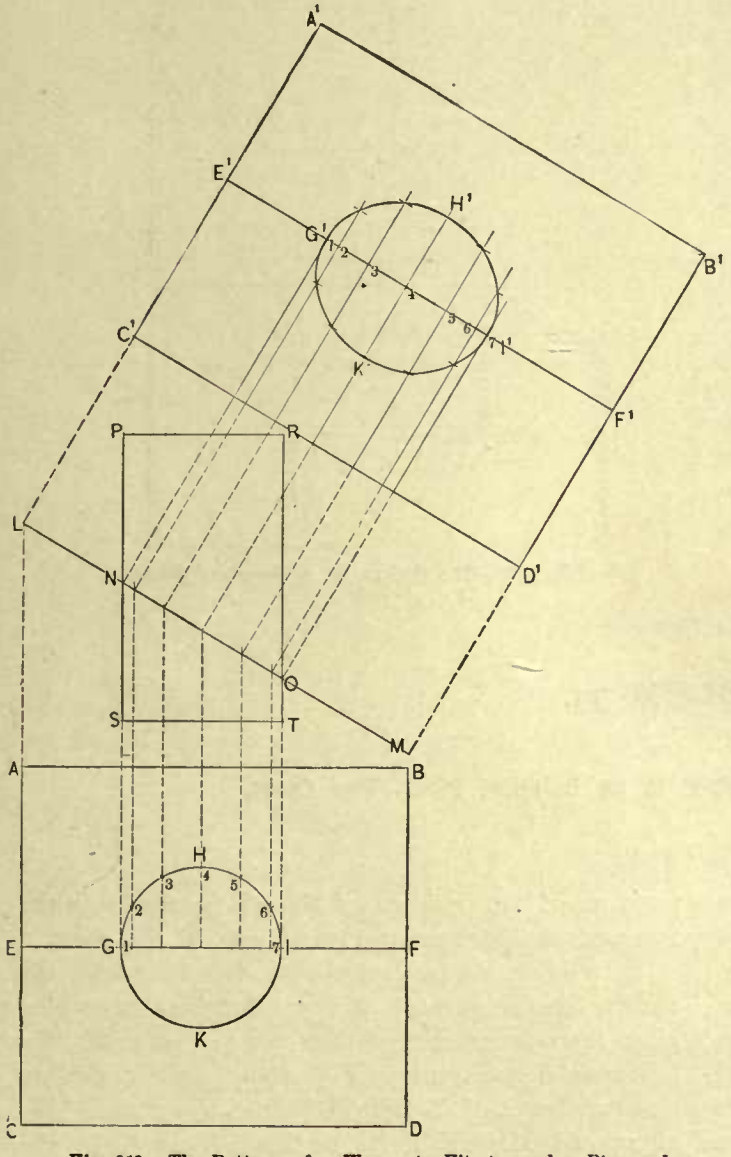


Fig. 316.—The Pattern of a Flange to Fit Around a Pipe and Against a Roof of One Inclination.

Let L M, Fig. 316, be the inclination of the roof and P R T S an elevation of the pipe passing through it. N O then represents the length of the opening which is to be cut in the flange, the width of which will be the same as the diameter of the pipe. Let A B D C be the size of the flange desired, as it would appear if viewed in plan. Immediately in line with the pipe draw the profile G H I K, putting it in the center of the plan of the flange A B D C, or otherwise, as required. Divide one-half of the profile in the usual manner, and carry lines vertically to the line L M, representing the pitch of the roof, and thence, at right angles to it, indefinitely. Carry points in the same manner from A and B. Draw C' D' parallel to L M. Make C' A' equal to A C, or the width of the required flange, and draw A' B' parallel to C' D'. Then C' A' B' D' will be the pattern of the required flange. Draw E' F' through it at a point corresponding to E F of the plan, crossing the lines drawn from the profile. From E' F' set off on each side, on each of the measuring lines crossing it, the width of opening, as measured on corresponding lines of the plan, measuring from E F in the plan to the profile. Through the points thus obtained draw a line, which will give the shape of the opening to be cut, all as shown by G' H' I' K'.

PROBLEM 38.

The Pattern for a Two-Piece Elbow.

In Fig. 317, let A C B D be the profile of the pipe in which the elbow is to be made. Draw an elevation of the elbow with the two arms at right angles to each other, one of which is projected directly from the profile, as shown by E G I H K F. Draw the diagonal line G K, which represents the joint to be made. Divide the profile into any convenient number of equal parts. Place the T-square parallel to the lines of the arm of the elbow, opposite the end of which the profile has been drawn, and, bringing the blade successively against the several points in the profile, drop corresponding points on the miter or joint line K G, as shown by the dotted lines. Opposite the end of the same arm, and at right angles to it, lay off a stretchout line, M N, divided in the usual manner, and through the divisions draw measuring lines, as shown. Place the blade of the T-square at right angles to the same arm of the elbow, or, what is the same, parallel to the stretchout line, and, bringing it successively against the points in K G, cut the corresponding measuring lines, as shown. A line traced through these points, as indicated by R P O, together with M N, will form the required pattern.

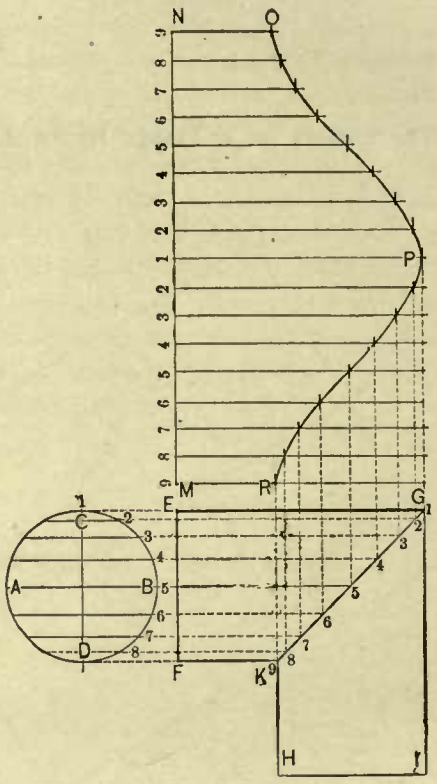


Fig. 317.—The Pattern for a Two-Piece Elbow.

PROBLEM 39.

The Patterns for a Two-Piece Elbow in an Elliptical Pipe.—Two Cases.

The only difference to be observed in cutting the patterns for elbows in elliptical pipes, as compared with the same operations in connection with round pipes, lies with the profile or section. The section is to be placed in the same position as shown in the rules for cutting elbows in round pipe, but it is to be turned broad or narrow side to the view, as the requirements of the case may be. In Figs. 318 and 319 are shown elevations and profiles of two right angled two-piece elbows in elliptical pipes. In Fig. 318 the broad side of the ellipse is presented to view, while Fig. 319 shows the narrow side, as indicated by the respective positions of the profiles. Although the results in the two cases are different in consequence of the position of the profiles, the method of procedure is exactly the same. Similar parts in the two drawings have been given the same reference letters and figures, so that the following demonstrations will apply equally well to either: Let A C E F D B be the elevation of the elbow and H G K I its section. Draw C D, the miter line. Divide the profile in the usual manner, as indicated by the small figures, and by means of the T-square placed parallel to the arm, drop points upon the miter line, as shown. Opposite the

end of the arm lay off a stretchout, M N, and through the points in it draw the usual measuring lines. Reverse the T-square, placing it at right angles to the arm, and, bringing it in contact with the several points in the miter line, cut the corresponding measuring lines. A line traced through these points, as shown by L P O, will constitute the required miter.

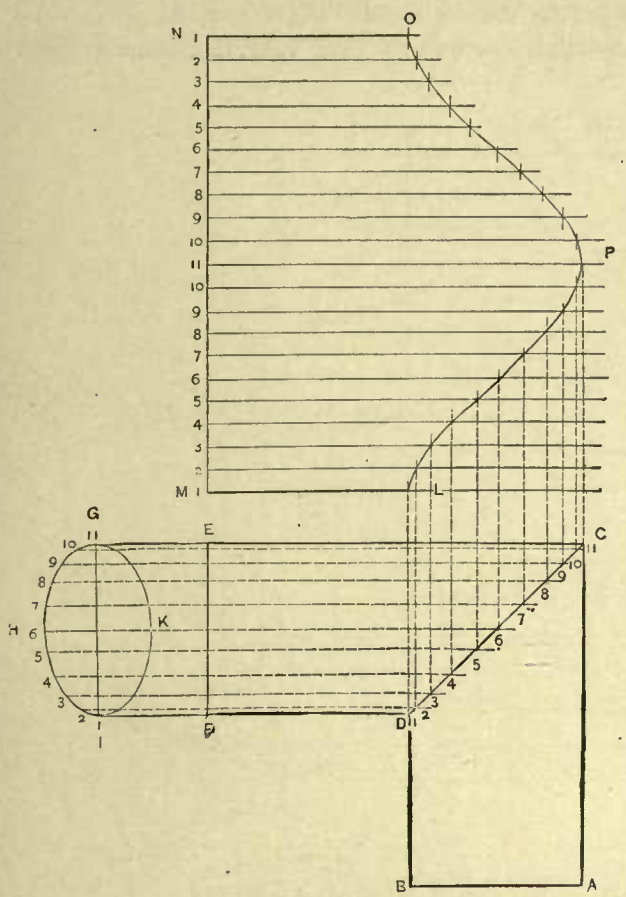


Fig. 318.

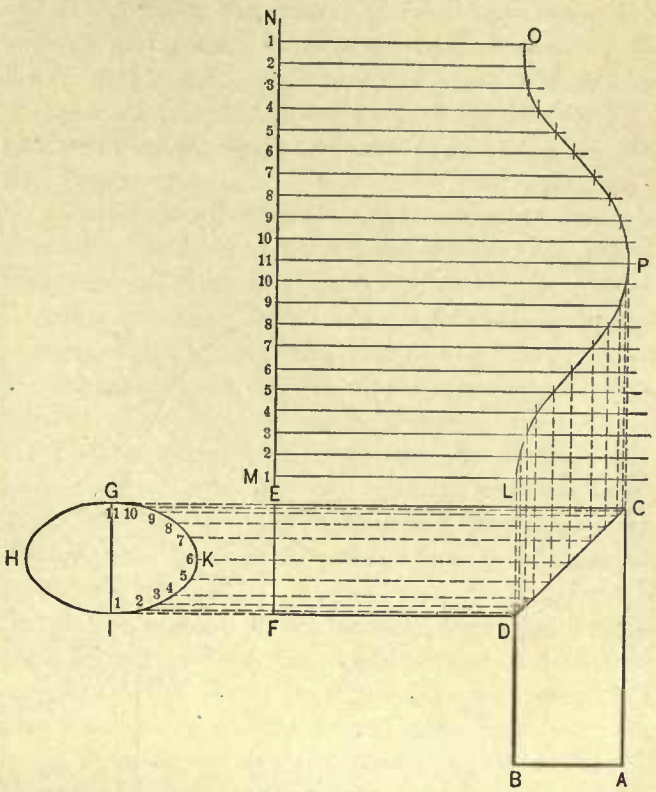


Fig. 319.

A Two-Piece Elbow in Elliptical Pipe.

PROBLEM 40.

The Patterns for a Three-Piece Elbow.

In Fig. 320, let E M L I H K N F be the elevation of a three-piece elbow. The drawing of a three-piece elbow, at any angle whatever, should be so constructed that the middle section or portion bears the same angle with reference to the two arms. Since the two arms in the present instance are at right angles (90 degrees) to each other, the middle section must therefore be drawn at an angle of 45 degrees to both. Make its diameter the same as that of the two arms, and draw the miter lines M N and L K. Draw the profile A B C in line with the arm from which the pattern is to be taken, as shown, and divide it into any convenient number of equal parts. Place the blade of the T-square parallel to this arm of the elbow, and, bringing it against the points in the profile, drop corresponding points upon the miter line L K. At right

angles to L I draw a stretchout, as R S, through the divisions in which draw measuring lines in the usual manner. Placing the T-square at right angles to L I, and bringing it successively against the points in the miter line L K, cut the corresponding measuring lines, drop like divisions upon M N. At right angles to L M lay off a stretchout of the profile A B C, as shown by P O, through the points in which draw measuring lines in the usual manner. Reversing the position of the set-square so that its long side shall come at right

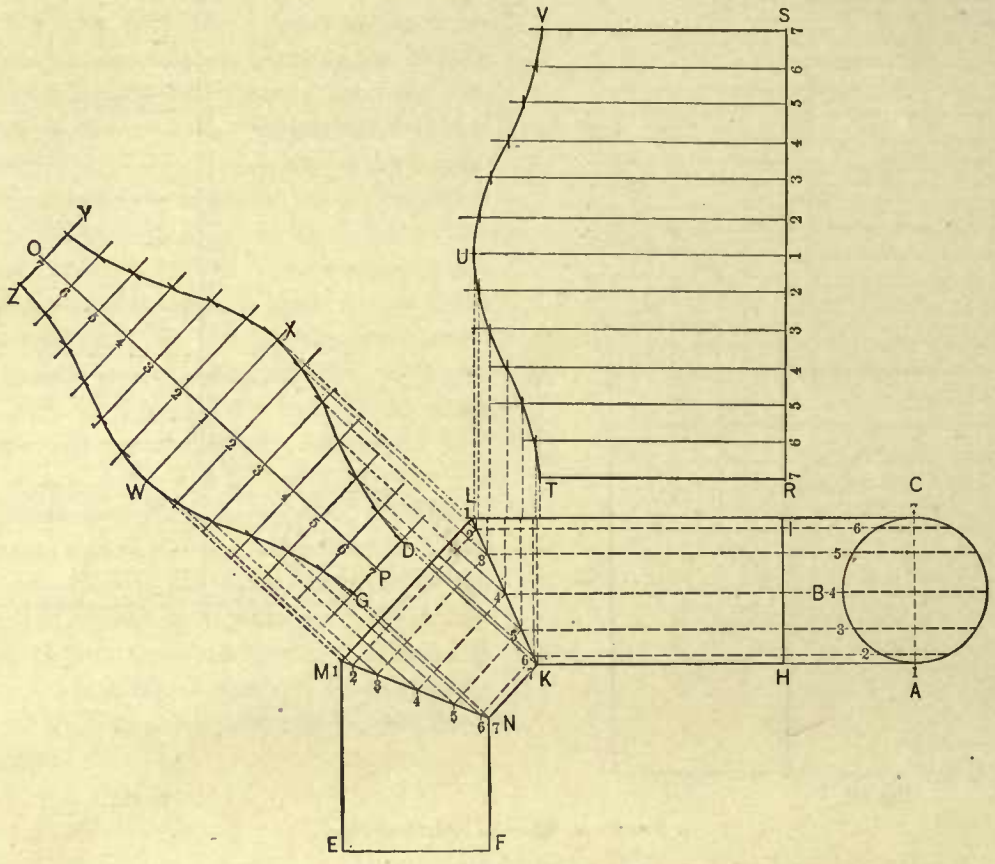


Fig. 320.—A Three-Piece Elbow.

as shown. Then the line T U V, traced through the points thus obtained, forms in connection with S R the pattern of an end section.

Place the 45-degree set square against the blade of the T-square so that its oblique or long side shall coincide with the lines of the middle section of the elbow, and, bringing it against the points in L K, angles to M L, or, what is the same, parallel to the stretchout line, bringing it successively against the several points in the miter lines M N and L K, and cut the corresponding measuring lines. Then lines traced through these points, as shown by D X Y and G W Z, will be the pattern of the middle section.

PROBLEM 41.

The Patterns for a Four-Piece Elbow.

In constructing the elevation of a four-piece elbow, first draw the profile A B C, from which project one of the arms of the elbow, as shown by the lines A F and C G, Fig. 321. At right angles to this lay off the other arm of the elbow, M L N I, continuing the lines of each until they intersect. Through the points of intersection draw the diagonal line *a d*. Establish the point *a* on this diagonal line at con-

venience, and from it draw the lines *a b* and *a c* at right angles to the two arms of the elbow respectively. From *a* as center, and with *a b* as radius, describe the arc *b f e c*, as shown, which divide into three equal parts, thus obtaining the points *f* and *e*. Through *f*

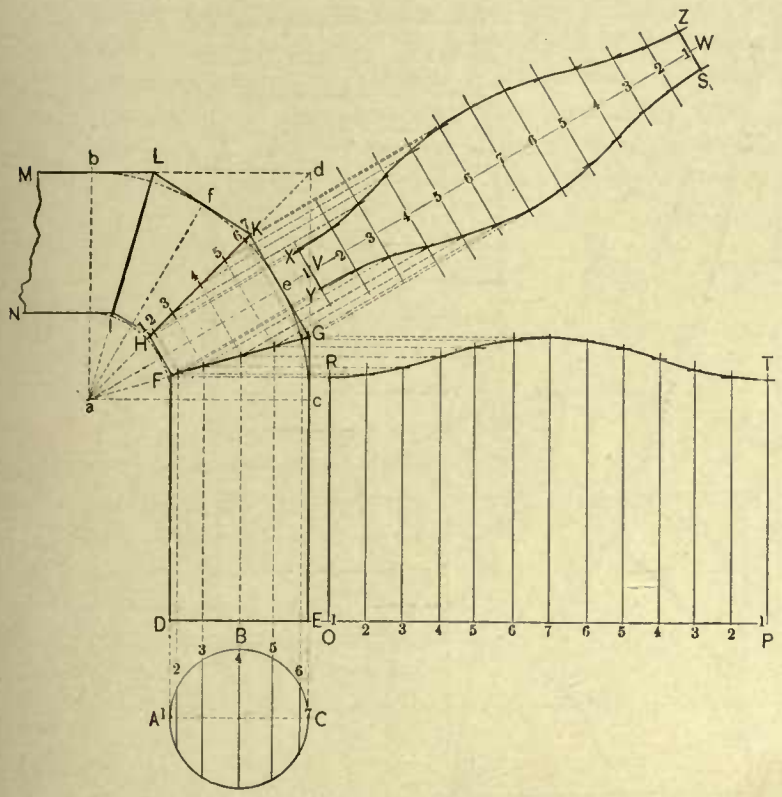


Fig. 321.—A Four-Piece Elbow.

and *e*, to the center *a*, draw the lines *f a* and *e a*, which will represent the centers of the middle sections of the elbow, at right angles to which the sides of the same are to be drawn. Through *f*, and at right angles to *f a*, draw L K, meeting M L in the point L, and stopping on the line *a d* at the point K. Through *e*, and at right angles to *e a*, draw a line, commencing in the point K and terminating in G where it meets the line E G. In like manner draw the lines of the inner side of the elbow, as shown by F H and H I. Draw the miter or joint lines F G, H K and L I, as shown. For the patterns proceed as follows: Divide the profile into any convenient number of equal parts. Place the T-square parallel to E G, and, bringing the blade against the points in the profile, drop corresponding points upon the miter line F G. Change the T-square so that its blade shall be parallel to the lines of the second section of the elbow, and, bringing it against the points in F G, cut corresponding points on H K. Opposite the end of and at right angles to the lower arm of the elbow, lay off the stretchout line O P, as shown, through the divisions in which draw the usual measuring lines. Place the T-square at right angles to the arm of the elbow, and, bringing it successively against the points in the miter line F G, cut the corresponding measuring lines. Then a line traced through the points thus obtained, as shown from R to T, will with O P constitute the pattern of one of the arms. Produce *a e*, representing the middle of the second section in the elbow, as shown by V W, upon which lay off a stretchout, and through the points in the same draw measuring lines. Placing the T-square parallel to *a e*, or, what is the same, at right angles to the second section of the elbow, bring it against the several points in the miter lines H K and F G, and cut the corresponding measuring lines. Then lines traced through the points thus obtained, as shown from X to Z and Y to S, will give the pattern.

PROBLEM 42.

The Patterns for a Five-Piece Elbow.

To construct the elevation of a five-piece elbow, first draw the profile, as A B C, Fig. 322, from which project one of the arms of the elbow, as shown at the left by E S R D, continuing its lines indefinitely. At right angles to this lay off the other arm, continuing its lines till they intersect those of the horizontal arm, or till their outer lines intersect, as at *g*. Draw *g a* at an angle of 45 degrees to either arm, upon which establish the point *a* with reference to the curve which it is desired the elbow shall have, and from it, at right angles to the two arms of the elbow respectively, draw *a b* and *a c*. From *a* as center, with *a b* as radius, describe the arc *b f e d c*, which divide into four equal parts, thus obtaining the points *d*, *e* and *f*, and draw *d a*, *c a* and *f a*. Then these lines represent center lines of the several sections of which the elbow is composed, at right angles to which their sides are to be drawn.

It may be here remarked that the number of

center lines made use of in dividing the quarter circle *b c* represents the number of pieces in the elbow. Therefore, to draw an elevation of an elbow in any number of pieces, construct the quadrant *a b c* as above described, then divide *b c* into such a number of parts that the number of lines drawn to *a* (including *a b* and *a c*) shall equal the number of pieces required. Thus the five lines *a b*, *a f*, *a e*, *a d* and *a c* are the center lines of the five pieces of which the elbow shown in Fig. 322 is constructed. Although the two extreme lines *a b* and *a c* are not, strictly speaking, center lines, their relation to the adjacent miter lines is the same as that of the other lines radiating from *a*. Through *f*, and at right angles to *f a*, draw V S, joining the side of the arm E S in the point S, and joining a corresponding line drawn through *e* in the point V. In like manner draw the line T R, representing the inner side of the same section. The remaining sections are to be obtained in the same way. As but one section is necessary for use in cutting the patterns, the others may or may not be drawn, all at the option of the pattern cutter. Draw the miter or joint lines S R, V T, etc. Divide the profile (or one-half of it) in the usual manner. Place the T-square parallel to the lines of the arm, and, bringing the blade against the several points in the profile, drop corresponding points upon the miter line S R. Shift the T-square so that the blade shall be parallel to the part V S R T, and transfer the points in S R to V T, as shown. For the pattern of the arm, at right angles to it lay off a stretchout of A B C, as shown by F G, through the points in which draw the usual measuring lines. Place the T-square at right angles to the arm, and, bringing it against the points in R S, cut the corresponding measuring lines, as shown. Then a line traced through these points, as shown from H to I, will be the pattern. For the pattern of the piece S V T R prolong the line *a f*, as shown by L K, upon which lay off a stretchout, through the points in which draw the measuring lines in the usual manner. Placing the T-square at right angles to S V, or, what is the same, parallel to the stretchout line, bring it against the several points in

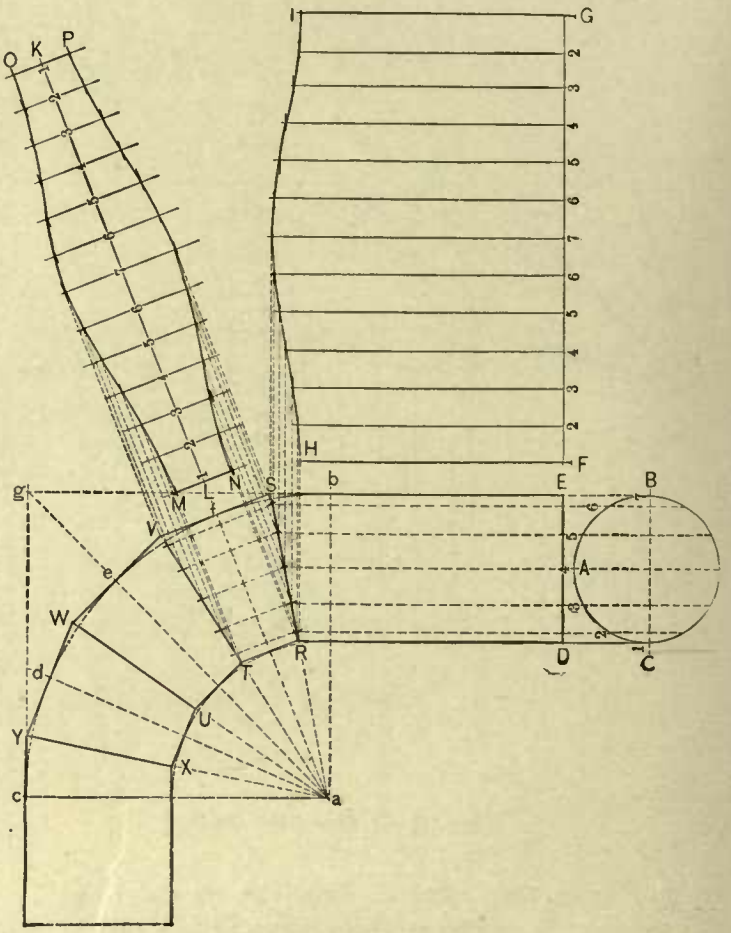


Fig. 322 —A Five-Piece Elbow.

the lines R S and T V, and cut the corresponding measuring lines. Then lines traced through the points thus obtained, all as shown by N P O M, will be the pattern sought.

PROBLEM 43.

The Patterns for a Pipe Carried Around a Semicircle by Means of Cross Joints.

In Fig. 323, let F E D be the semicircle around which a pipe, of which A C B is a section, is to be carried by means of any suitable number of cross joints, in this instance ten. Divide the semicircle F E D into the same number of equal parts as there are to be joints, which, as just stated, is to be ten, all as shown by D, O, P, R, S, E, etc., and draw lines from each point to Z. As there are to be ten joints there must necessarily be eleven pieces, therefore, according to the directions given in the previous problem, the semicircle must be divided into such a number of equal parts that the number of lines radiating from Z

shall be eleven, all as shown, each line serving as the center line of a piece. From D toward the center Z set off the diameter of the pipe A B, as shown by the point A^1. From Z as center, with the radius Z A^1, draw the dotted line representing the inner line of the pipe, and cutting the radial lines previously drawn in the points O^1, P^1, etc. Through O and O^1 draw lines at right angles to O Z and continue them in either direction till they intersect with the lines drawn through P and P^1 on the one side and through D and A^1 on the other. Each pair of lines is to be drawn at right angles to its respective radial or center line. Through the points of intersection draw the lines T T^1, U U^1, etc., which will represent the lines of the joints or miters.

It will appear by inspection that the point U is equidistant from P and O, and that U^1 is also equidistant from P^1 and O^1, and that therefore the lines U U^1, T T^1, etc., if continued inward must arrive at the center Z. Thus the joint lines, like the center lines, must radiate from the center of the semicircle.

Draw the profile of the pipe A C B directly below and in line with one end of the pipe, all as shown in the engraving. As may be seen by inspection of the diagram, two patterns are required, one corresponding to the half section occurring at the end, and the other corresponding to the full sections composing the body of the pipe. For the pattern of the end section proceed as follows: Divide the profile A C B in the usual manner into any convenient number of equal parts, and from the points thus obtained carry lines upward at right angles to Z D, cutting T^1 T. Prolong the line Z D, and upon it place a stretchout from the profile A C B, perpendicular to which draw measuring lines in the usual manner. With the T-square placed parallel to Z D, and brought successively against the points in T^1 T, cut the measuring lines of corresponding numbers. Then a line traced through the points of intersection thus obtained, as shown by I K L, will be the shape of the miter cut, and G I K L H will be the complete pattern for one of the end pieces. For the pattern of one of the large pieces, as U V V^1 U^1, lay off a stretchout of A C B upon its center line extended, as shown by M N, and through the points in it draw measuring lines in the usual manner. Place the T-square parallel to U V and, bringing it against the points in U U^1, cut the line V V^1. Next place the T-square parallel to the stretchout line, and, bringing it against the several points in the miter lines U^1 U and V^1 V, cut the corresponding measuring lines, all as shown, thus completing the pattern.

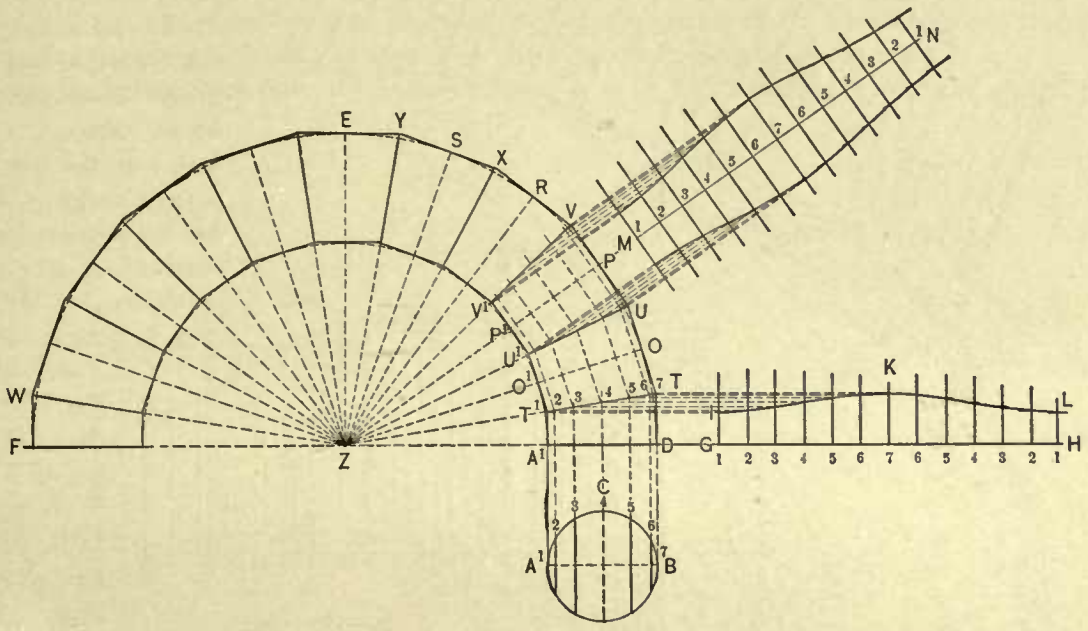


Fig. 323.—A Pipe Carried Around a Semicircle by Means of Cross Joints.

PROBLEM 44.

The Patterns for an Elbow at Any Angle.

Let D F H K L I G E in Fig. 324 be the elevation of a pipe in which elbows are required at special angles. In convenient proximity to and in line with one end of the pipe draw a profile, as shown by A B C, which divide in the usual manner. Placing the T-square parallel to the first section of the pipe, and, bringing it against the several points in the profile, drop corresponding points upon F G. Shift the T-square, placing it parallel to the second section, and, bringing it against the several points in F G, drop them upon H I. At right angles to the first section lay off a stretchout of A B C, as shown by T U, through the points in which draw the customary measuring lines. Placing the T-square at right angles to this section of the pipe, and bringing it against the several points in F G, cut the corresponding measuring lines. Then the line R L S traced through these points will, with the line T U, be the pattern sought. The pattern for the opposite end is to be obtained in like manner, all as shown by M N O P, and therefore need not be described in detail. For the pattern of the middle section lay off a stretchout, W V, at right angles to it, with the customary measuring lines. Placing the T-square at right angles to the section, bring it successively against the points in G F and I H, and cut the corresponding measuring lines, as shown. Then lines traced through these points, as shown by Y X Z Q, will be the pattern sought. The positions of the longitudinal joints in the several sections of this elbow, as well as those of all others, are determined by the order in which the measuring lines drawn through the stretchout are numbered. In the present instance the joints are allowed to come on the back of the pipe, or, in other words, upon D F H K, which corresponds to the point 1 in the profile. Hence, in numbering the measuring lines in the several stretchouts, point 1 is placed at the commencement and ending, while if it were desired to have the joint in either piece come on the opposite side, or at a point corresponding to 9 of the profile, the stretchout would have commenced and ended with that figure, the

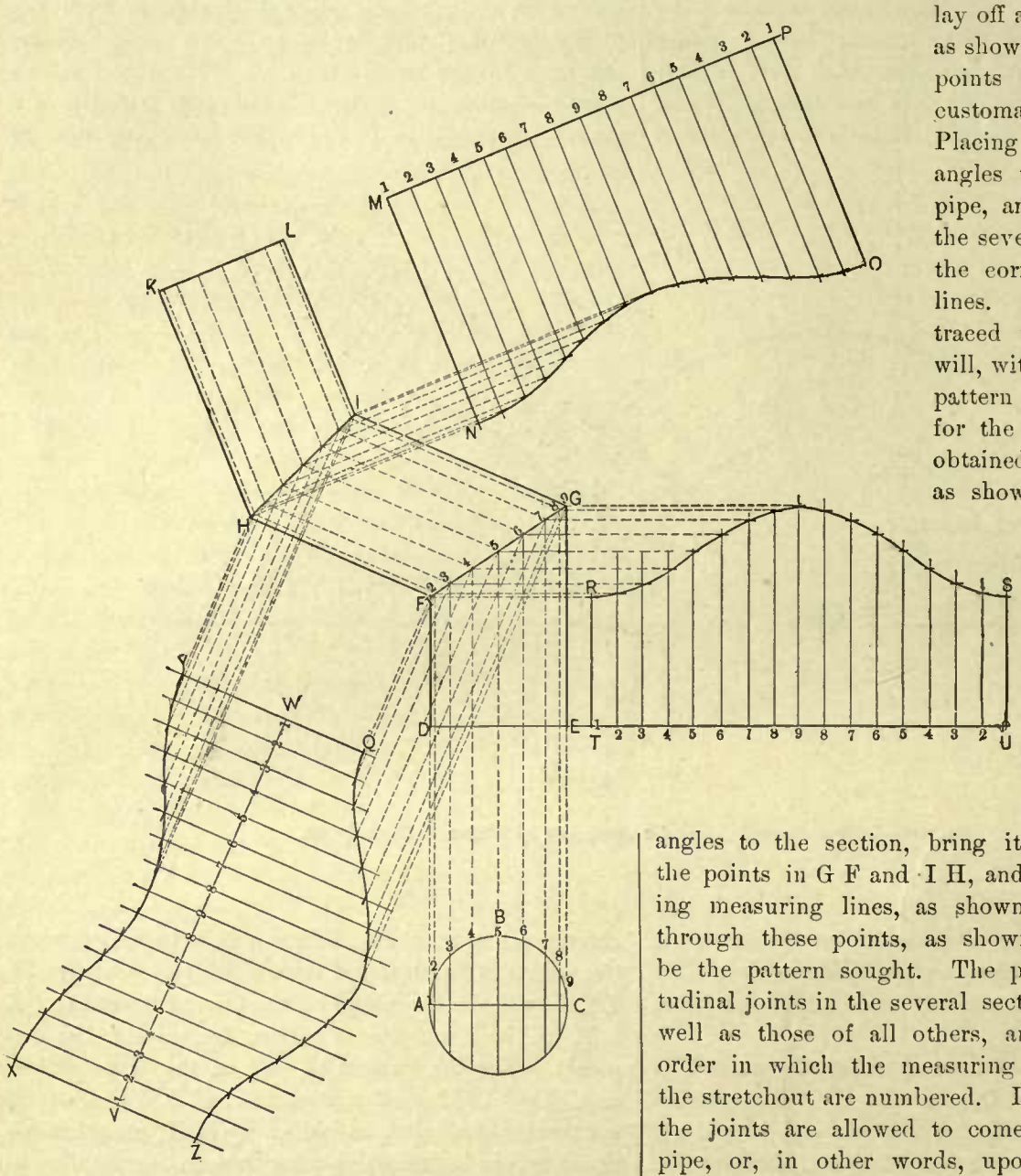


Fig. 324.—An Elbow at Any Angle.

figure 1 in that case coming, in regular order, where 9 now occurs. The effect of such a change upon any of the patterns here given would be the same as if they were cut in two upon the line 9 and the two halves were transposed.

PROBLEM 45.

The Patterns for a Bifurcated Pipe, the Two Arms Being the Same Diameter as the Main Pipe, and Leaving It at the Same Angle.

In Fig. 325 is shown an elevation of a bifurcated pipe, all arms being of the same diameter. In this problem, as in many others, it becomes necessary to first make a correct drawing of the intersection of the parts showing the miter lines correctly; after which the method of laying out of the miter patterns is the same as that employed in several other problems immediately preceding this. If, in this case, each arm of the pipe be divided longitudinally into two equal parts, as shown by the center lines, and each half be considered as a separate molding the correct position of the miter lines will at once be determined. Thus the intersection of the three bisecting lines at R gives the point at which the miter lines starting from the points P, E and K must meet.

In line with the upper end of the pipe draw a profile of it, as shown by A C B. A profile will also be needed in one of the oblique arms, a half only being shown at A′ C′ B′ on account of the limited space. For the pattern of the upper portion of the pipe, divide the profile A C B into any number of equal spaces, and place the stretchout of the same on

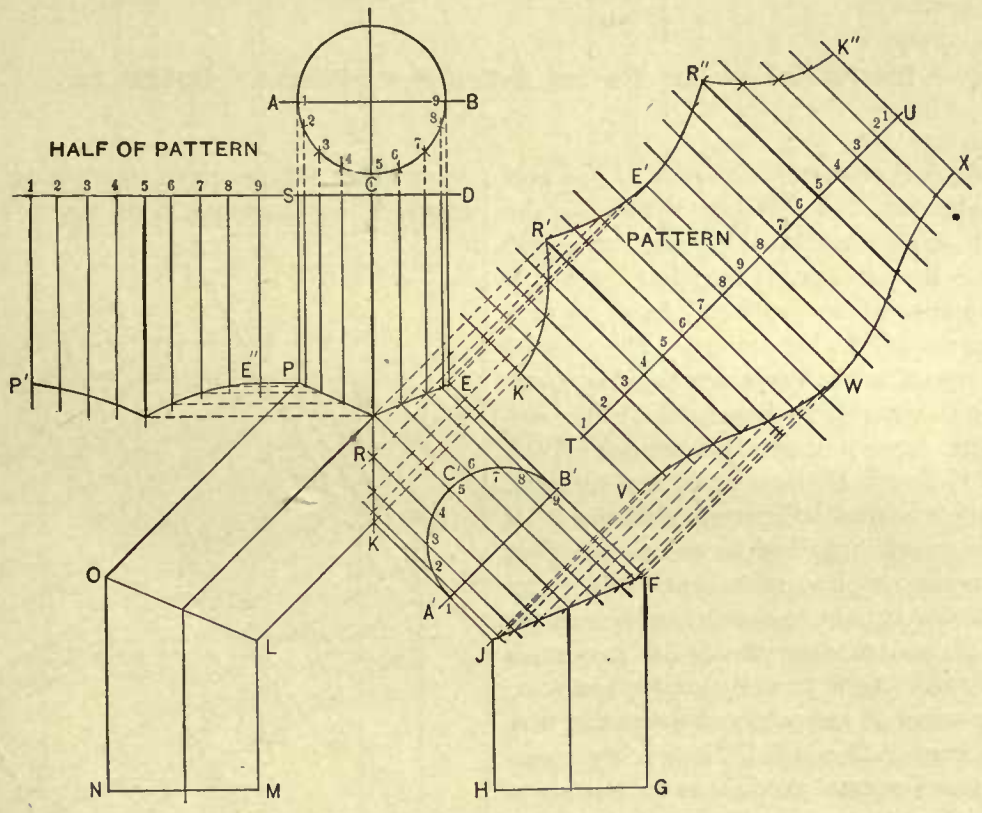


Fig. 325.—The Pattern for a Bifurcated Pipe.

any line drawn at right angles to S P, as shown by the continuation of S D to the left, and draw the usual measuring lines. Next drop the points from the profile A C B parallel with S P till they cut the miter line P R E; then placing the T-square at right angles to S P, drop the points from the miter line P E into measuring lines of corresponding number. A line traced through these points of intersection, as shown from E″ to P′, will give the miter cut on the lower end of the pipe S D E P, one-half of which only is shown in the engraving. The pattern for the piece E F J K is obtained in exactly the same manner, and might be obtained, so far as the half indicated by C′ B′ on profile is concerned, from the original profile, by simply continuing the lines through to the miter line J F, as shown. For simplicity, therefore, the profile A′ C′ B′ is divided into the same number of equal parts as the original profile, and a stretchout of it is placed upon any line, as T U, drawn at right angles to E F. The points are then dropped from the profile both ways, cutting the miter lines K R E and J F, after which, with the T-square placed parallel to T U, they can be dropped into the measuring lines of the stretchout. Lines traced through the points of intersection will constitute the required pattern, as shown by K′ R′ E′ R″ K″ X W V.

PROBLEM 46.

The Patterns for the Top and Bottom of a "Common" Skylight Bar.

In Fig. 326, A B represents a portion of the profile of the ridge bar, or of the ventilator forming the top finish of a skylight, against which the upper end of a "common" bar is required to miter; and C D represents the profile of the curb or finish against which the lower end of the bar miters. The parallel oblique lines connecting the two show the side elevation of the bar whose profile is shown at E F F'.

As the profile consists of two symmetrical halves, either half, as E F or E F', may be chosen to work from, and as it contains no curved portions it is simply necessary to number all of its points or angles, and then to place a complete stretchout of the same upon any line drawn at right angles to the lines of the molding, as G H, and to draw the usual measuring lines, all as shown. As a properly drawn elevation shows the intersection of the points of the profile with the two miter lines A B and C D', it is only necessary to place the T-square parallel to the stretchout lines G H, and bring it successively against the points in A B and C D', and cut corresponding measuring lines, as shown at I J and K L. Straight lines connecting the points of intersection will complete the pattern, as shown at I J L K. The length of the pattern, which is here shown indefinite, must be determined by a detail drawing, in which the rise M B and the run M D' are correctly given.

The patterns for the "jack" bar and for the "hip" bar will be given later among those problems in which the development of the miter line and the raking of the profile are necessary, with which they are properly classed.

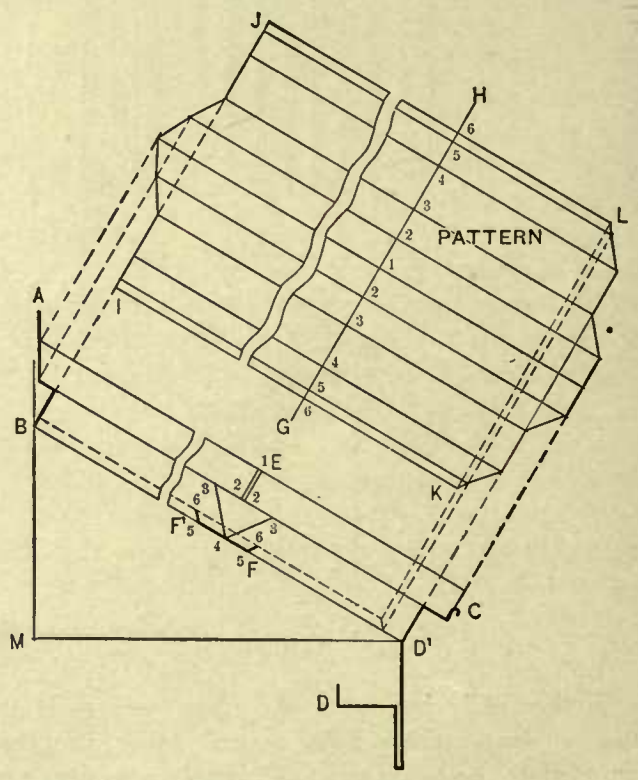


Fig. 326.—The Patterns for a "Common" Skylight Bar.

PROBLEM 47.

The Patterns for a T-Joint Between Pipes of the Same Diameters.

Let D F G H M I K E in Fig. 327 be the elevation of two pipes of the same size meeting at right angles and forming a T, of which A B C D and A' B' C' D' are profiles drawn in line with either piece. As the two profiles are alike, and as the end of one piece (D E F K) comes against the side of the other piece (G I M H), both halves of D E F K, B A D and B C D, will miter with one-half, B' C' D', of the piece G I M H. By projecting the points B and B' from the profiles through their respective elevations the point L is found, which being connected with the points F and K gives the miter lines. Space the profile A B C D into any number of equal parts and lay off the stretchout N O at right angles to the pipe of which A B C D is the profile, as shown, through the points in which draw the usual measuring lines. Set the T-square at right angles to this pipe, and, bringing the blade against the several points on the miter lines, cut the corresponding measuring lines drawn through the stretchout, as indicated by the dotted lines. Then N F' U V W O will be the pattern for the upper piece. As both halves of this piece (dividing now upon the line A C) will be alike only one-half of the profile (A B C) has been divided, but the stretchout is made complete. For the pattern of the other piece, divide its profile into any convenient number of equal parts and lay off the stretchout on the line R T, drawn at right angles to the pipe. Placing the T-square parallel with the pipe drop points upon the miter lines from that portion of the profile (B' C' D') which comes in line with them; then place the blade of the T-square at right angles to the pipe, and, bringing it against the several points in the miter lines, cut the corresponding measuring lines, as shown by the dotted lines. A line, X Y Q Z, traced through these points will bound the opening to be cut in the pattern for the lower pipe. From the points 1 in the stretchout draw the lines R P and T S, in length equal to the length of the pipe. Connect P S. Then P R T S will be the required pattern. The seam in the pipe may be located as shown in the engraving, or at some other point, at pleasure.

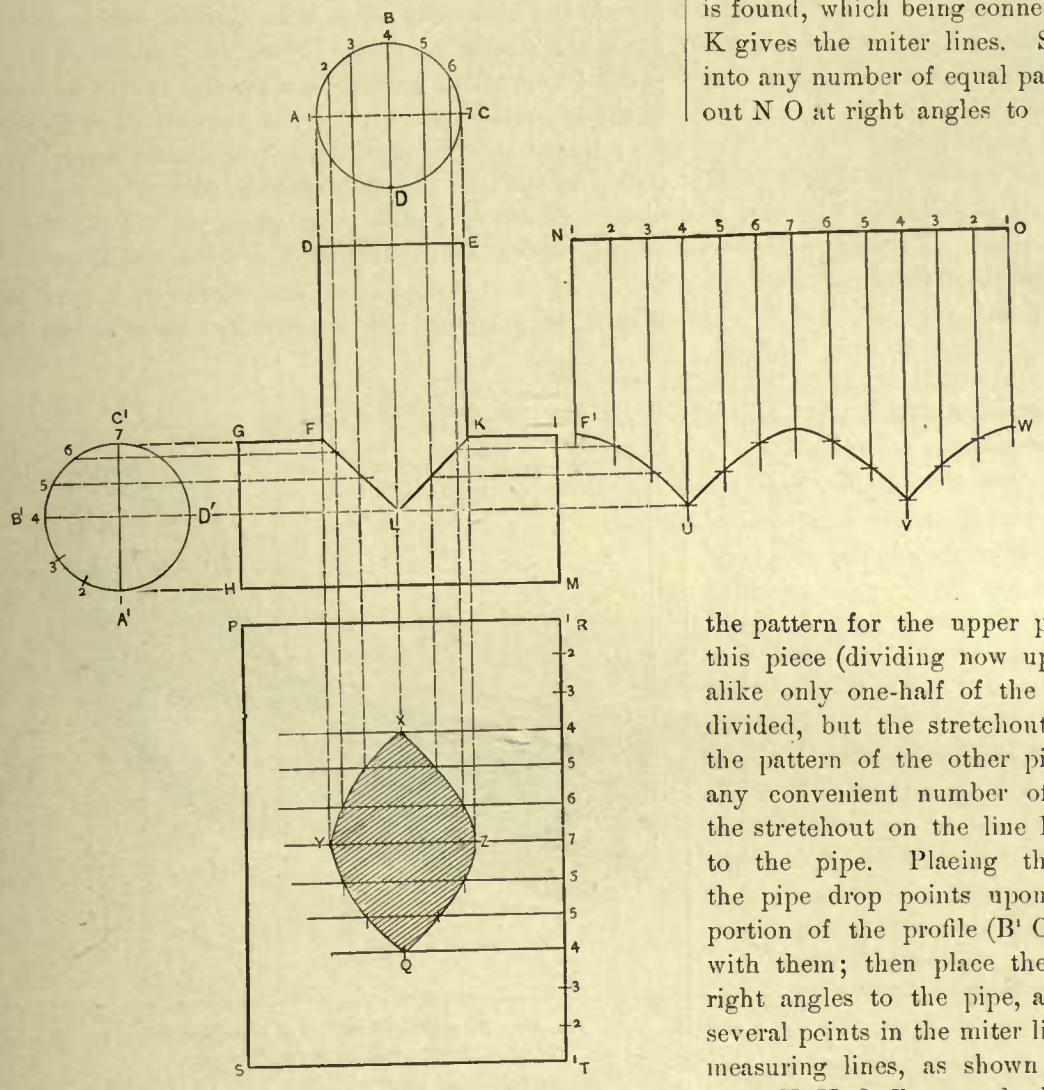


Fig. 327.—A T-Joint between Pipes of the Same Diameter.

PROBLEM 48.

The Patterns for a Square Pipe Describing a Twist or Compound Curve.

As problems of this nature frequently occur in connection with hot air pipes, grain chutes, etc., this problem is given as embodying principles which can often be made use of. The upper opening of the pipe in this case is required to be in a horizontal plane, while the lower opening is in a vertical position and placed at a given distance below and to one side of the top, the pipe describing a quarter turn when viewed from either the top or the front.

To more fully illustrate the nature of the problem, a perspective view of it is shown in Fig. 328, in which the pipe is represented as being contained within a cubical shaped solid. The solid, of which the pipe is represented as forming a part, is shown in outline, the pipe itself being shaded to show its form, while upon the front and lower side of the solid are shown in dotted lines the front elevation and plan of the pipe. Thus G F T C represents the front view of a solid just large enough to contain the pipe, in which A B C D shows the position of the lower opening, and A B E F D C shows the curve of the pipe as seen from the front. G H S F is the top of the solid in which the upper opening N P S R is situated. The curve of the pipe in plan has been projected to the lower face of the solid by vertical lines, R L, and others not shown, and is shown by C J K L M D. To state the case simply, then, A B E is the profile of the piece of metal forming the top of the pipe, while D M L and C J K are the two miter lines, or the plans of the intersecting surfaces, and C D F is the profile of the lower side of the pipe intersecting the same miter lines. The top and bottom pieces being developed, it is only necessary to reverse the operation and consider the lines of the plan D M L and C J K as the profiles of the front and back pieces respectively, while A B E and C D F become the miter lines or elevations of the intersecting surfaces.

A part of these operations are carried out in detail in Fig. 339, where the elevation and the plan are drawn directly in line with each other; the various points being represented by the same letters in the two illustrations. For the pattern of the top piece divide its profile A B E by any convenient number of points (1, 2, 3, etc.), from which drop lines vertically cutting the two miter lines D′ M and C′ J of the plan, as shown (the figures of the plan 2 to 11 have no reference to this part of the operation). Upon R 8, drawn at right angles to the direction of the mold, lay off the stretchout of A B E, through which draw the usual measuring lines. With the T-square placed parallel to R 8 and brought against the several points in the two miter lines cut lines of corresponding number; lines traced through the points of intersection, as shown by R T and U S, will give the pattern of the top piece. It will be noticed that owing to the contrary relation of the two curves it is necessary to have the points of the profile occur more frequently near B than E, as otherwise they would intersect the miter

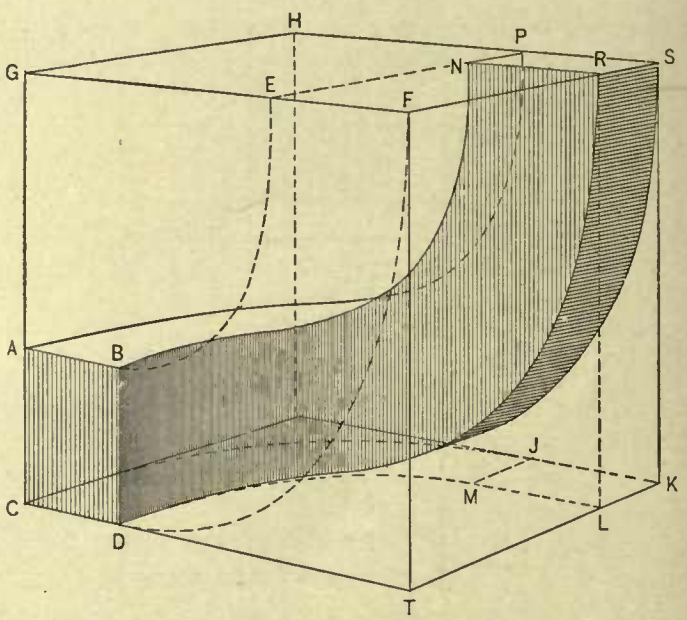


Fig. 328.—Perspective View of a Pipe Describing a Twist or Compound Curve.

line D′ M too far apart near D′, while they would occur more frequently than is necessary near M. As there is no curve from A to B of the profile, that part of the pattern from R to S will be a duplicate of the plan view, consequently the curve from R to the measuring line drawn from S may be traced from the plan. The development of the pattern for the lower

side of the pipe is not given, but it would be accomplished in exactly the same manner as that of the top piece, using C D F as the profile instead of A B E.

For the pattern of the front pieee of the pipe, divide its profile L M D′ by any convenient number of points 1, 2, 3, 4, etc., from which drop lines vertically, cutting the two miter lines D F and B E, as shown. Upon Q 1, drawn at right angles to the direction of the mold, place the stretchout of L M D′, through which draw the usual measuring lines. With the T-square placed parallel to Q 1 and brought against the various points in B E and D F cut corresponding measuring lines. Lines traced through the points of intersection, as shown by Q P and O N, will give the required pattern.

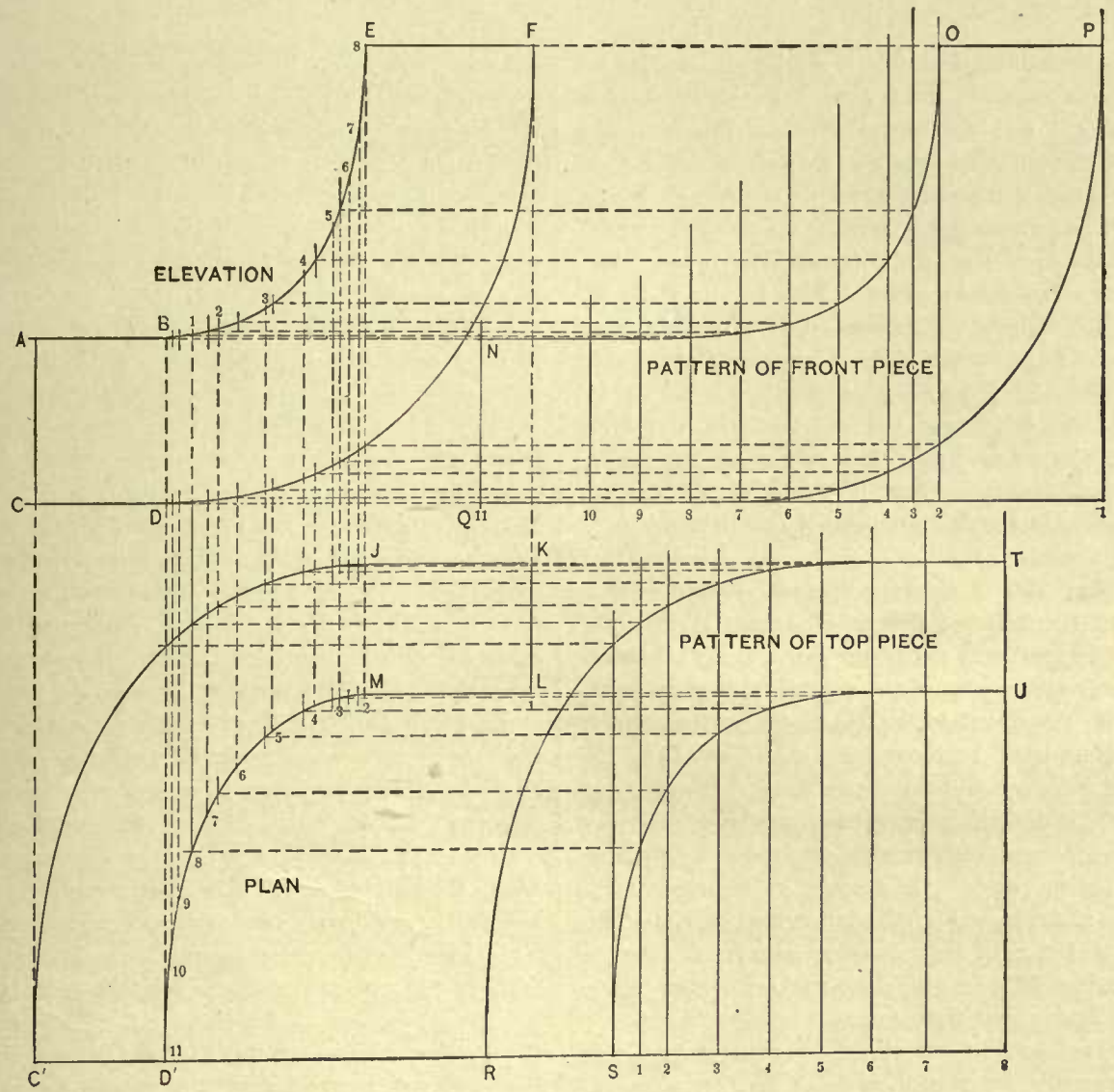


Fig. 329.—Patterns for a Pipe Describing a Compound Curve.

The pattern of the back piece not given in the illustration can be developed in exactly the same manner as that of the front by using C′ J K as the profile and proceeding otherwise the same as in the foregoing.

PROBLEM 49.

The Construction of a Volute for a Capital.

It is sometimes desirable in designing capitals of large size to construct the volutes of the same of strips of metal cut and soldered together. The principal characteristic entering into the design of the volute, and that which distinguishes it from an ordinary scroll, consists in a pulling out or raising up of each successive revolution of the scroll beyond the former, thus producing a ram's horn effect. This feature of its design is also frequently embodied in the construction of scrolls used to finish the sides of large brackets or head blocks, such as may be seen by reference to Fig. 87 on page 12. As all volutes, except those of the Ionic order, always occur under the corners of the abacus and project diagonally from the bell of the capital, their forms can only be correctly delineated in a diagonal elevation.

In Fig. 330 is shown a diagonal elevation of a portion of the bell and abacus of a capital with the volute. Immediately below the same, D A C B shows one-quarter of the plan of the capital, turned to correspond with the elevation, in which the various curves of the volute have been carefully projected from the elevation, as shown by the dotted lines. As the pattern cutter is dependent upon the drawing of the plan for his miter lines, considerable care must be given to this part of the work. On account of the small scale necessary in drawing Fig. 330, an enlarged view of the plan of the helix of the volute, as seen from below, is shown in Fig. 331, in which the various curves can be followed throughout their course.

The volute as here given consists of two side pieces or scrolls, an outside cover or face strip, an inside cover and two narrow strips to fill the space where the second curve of the scroll projects beyond the first. The outside cover or face strip extends from F of the elevation to G, where it is met by the inside face strip, which begins at H. To obtain the pattern for the inside cover, divide the profile from H to G into any convenient number of equal spaces, and lay off a stretchout of the same upon the center line of the volute in plan, A B, extended toward K, as shown by the nine spaces on the upper side of the line. Drop lines vertically from each of these points intersecting the upper line of the side of the scroll in plan. Place the T-square parallel to the stretchout line B K, and bringing it successively against the points in the plan, drop lines cutting corresponding lines of the stretchout. Then a line traced through the points of intersection, as shown from I to J, will give the shape of the side of the strip to cover the space between the points H and G of the elevation. A similar course is to be pursued in obtaining the outside cover or strip extending from F to G. This stretchout consists of fourteen spaces, and is shown on the lower side of the center line A K, the pattern being shown from L to M. The pattern for the remaining strip consists of a stretchout of seven pieces taken from the profile between G and the termination of the scroll line. Points from this part of the profile are intersected with two miter lines in the plan, one forming the outer line of the strip, or its finish against the more projecting part of the scroll, and the other forming its finish against the lower scroll or inner edge of its first or outer curve. In Fig. 331 the lines showing the projection of the inner part of the volute beyond the outer curve are clearly seen. In the lower half the lines corresponding to the points 1 to 7 of the profile are shown by corresponding numbers. Lines dropped from the points on both these lines to corresponding lines of the stretchout will give the pattern as shown from M to N.

By inspection of the drawing it will be seen that the outline of the volute, as given in the elevation, does not represent exactly the "true face" of the scroll. As the variations in the angle of the side of the central part or helix of the scroll are only such as can be produced by the springing of the metal necessary to bring it into shape, no allowance need be made for such variation in cutting the pattern directly from the elevation. Careful measurements of the stem or lower part of the volute, as shown in the plan, however, show that the distances from point 9 to points *a* and *b*, if laid off on a line parallel to A B, would reach to points a^2

and b^2. These points projected back into the elevation locate them in that view at a^3 and b^3. Therefore the outline of the back of the stem will have to be extended as shown by the dotted line from F to a^3. This outline can be accurately obtained, if deemed necessary, by the raking process described in connection with a number of other problems in this section of this chapter, and need not be repeated here. The correct outline, from G to b^2 is omitted to avoid confusion with the figures.

To avoid confusion of lines in dropping the points from the different parts of the profile to the miter lines and thence to the stretchout, only the first and last of each series or stretchout have been shown by dotted lines in the drawing.

Fig. 331.—Enlarged View of Helix.

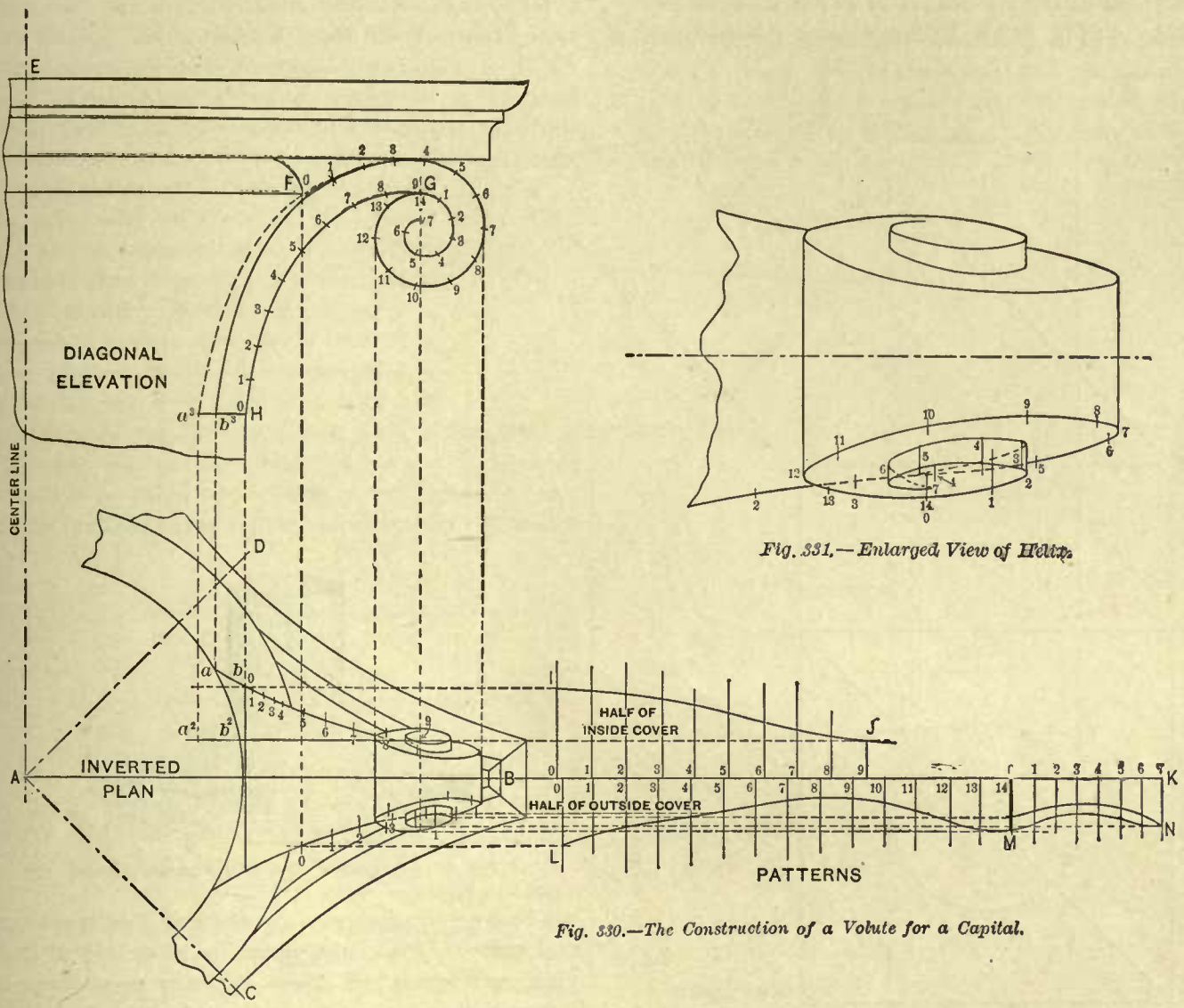


Fig. 330.—The Construction of a Volute for a Capital.

PROBLEM 50.

The Pattern for a Pyramidal Flange to Fit Against the Sides of a Round Pipe Which Passes Through Its Apex.

A pictorial illustration of the flange fitting against the sides of the pipe, as stated above, is shown in Fig. 332. In Fig. 333 K L M represents the elevation of

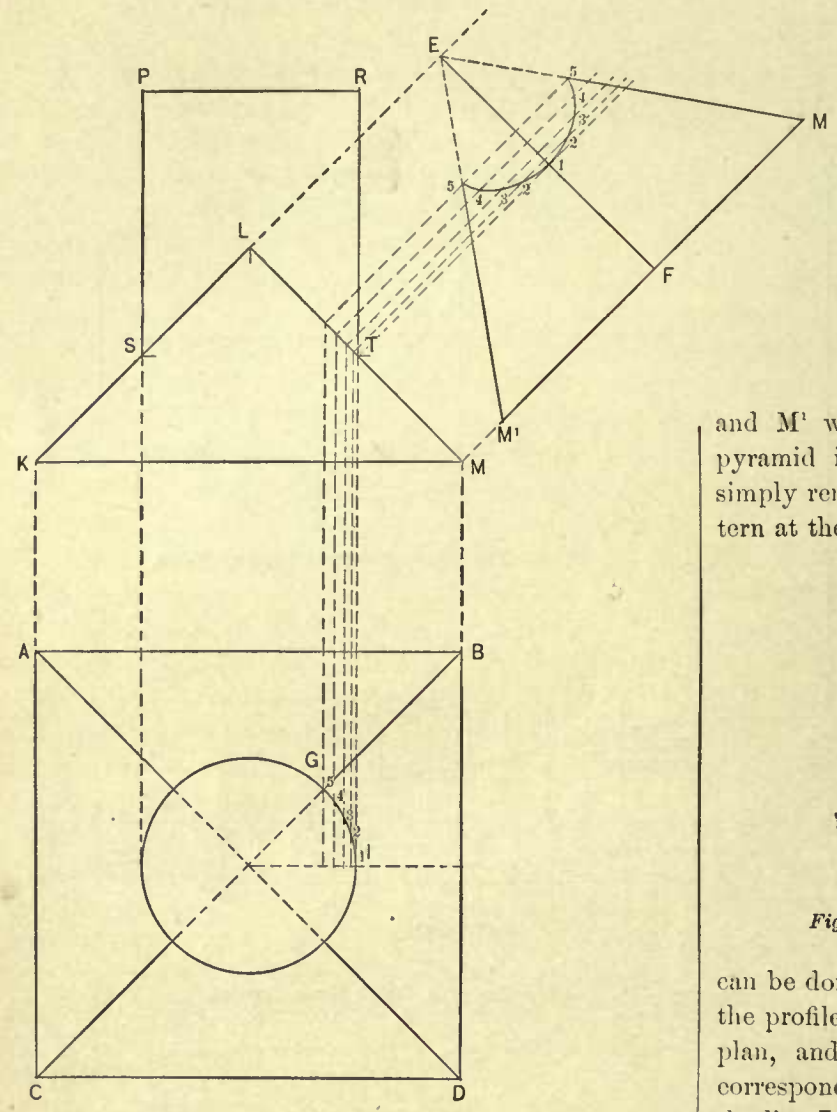


Fig. 333.—Pattern for a Pyramidal Flange to Fit Against a Round Pipe.

pyramid, and P R T S elevation of the pipe that is to pass through it, A B D C being plan of pipe and pyramid. As the pyramid has four sides, each side will miter or fit against one-quarter of the profile of the pipe, as will be seen by reference to the plan. Again, as each side consists of two symmetrical halves, as shown by the dotted line dividing the side B D, one-eighth of the profile of the pipe (as G I) is all that need be used in obtaining the pattern. Therefore, divide G I into any convenient number of parts and carry vertical lines to L M, which represents one side of the pyramid, and then, from these points and the points L and M carry lines at right angles to it indefinitely, as shown. L M in the elevation represents the complete length of one side of the pyramid, as it would be if not cut by the pipe. Lay off on the line from M the length of one side of the base of the pyramid, as B D in the plan, as shown by M M'. Bisect M M' at F, from which point draw F E parallel to L M, cutting the line from point L at E. The lines from E to the points M and M' would give the pattern of one side of the pyramid if it were not to be cut by the pipe. It simply remains now to measure the width of the pattern at the various points of the curved portion, which

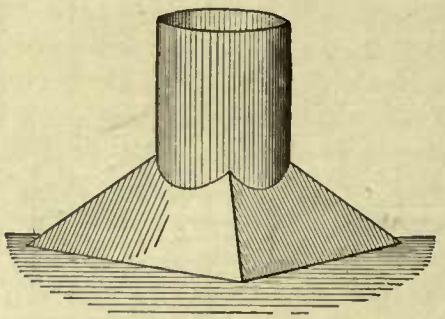


Fig. 332.—Perspective View of Pyramidal Flange.

can be done by measuring the distance of each point in the profile G I, from the center line of the side B D in plan, and setting off these distances upon lines of corresponding number drawn through the pattern from the line L M, measuring each time from the center line E F. Thus the distance of point 4 from the center line in plan is set off from the center line of the pattern each way upon line 4, and coincides with this point as previously established by the lines drawn from E to M and M'. The distance of the point 3 from the center line in the plan is set off from the center line of pattern each way upon line 3 of the pattern. Point 2 is established in the same manner. A line traced through the points 4 3 2 1 2 3 4 completes the pattern.

PROBLEM 51.

The Patterns for a Square Pyramid to Fit Against the Sides of an Elliptical Pipe Which Passes Through Its Center.

In Fig. 334, A B C D shows the plan of a square pyramid, whose apex, if completed, would be at E. F H I J shows the horizontal section of an elliptical pipe, against the sides of which the sides of the pyramid are required to be fitted. From the side A B (or D C) of the plan is projected a front elevation, in which K L M N shows the broad side of the pipe. To the right another or side elevation is projected, in which the narrow view of the pipe is shown by O P Q R. An inspection of the plan will show at once that two patterns will be necessary, one for A B G S to fit against the broad side of the pipe, and another for B G T C to fit against what might be termed the edge or narrow side of the pipe. To obtain the pattern of the side of the pyramid shown by B G T C (or B E C, if the pyramid were complete), first divide that portion of the profile of the pipe from G to H by any convenient number of points, as shown by the small figures, from which, together with B and E, project lines vertically to the elevation above, cut-

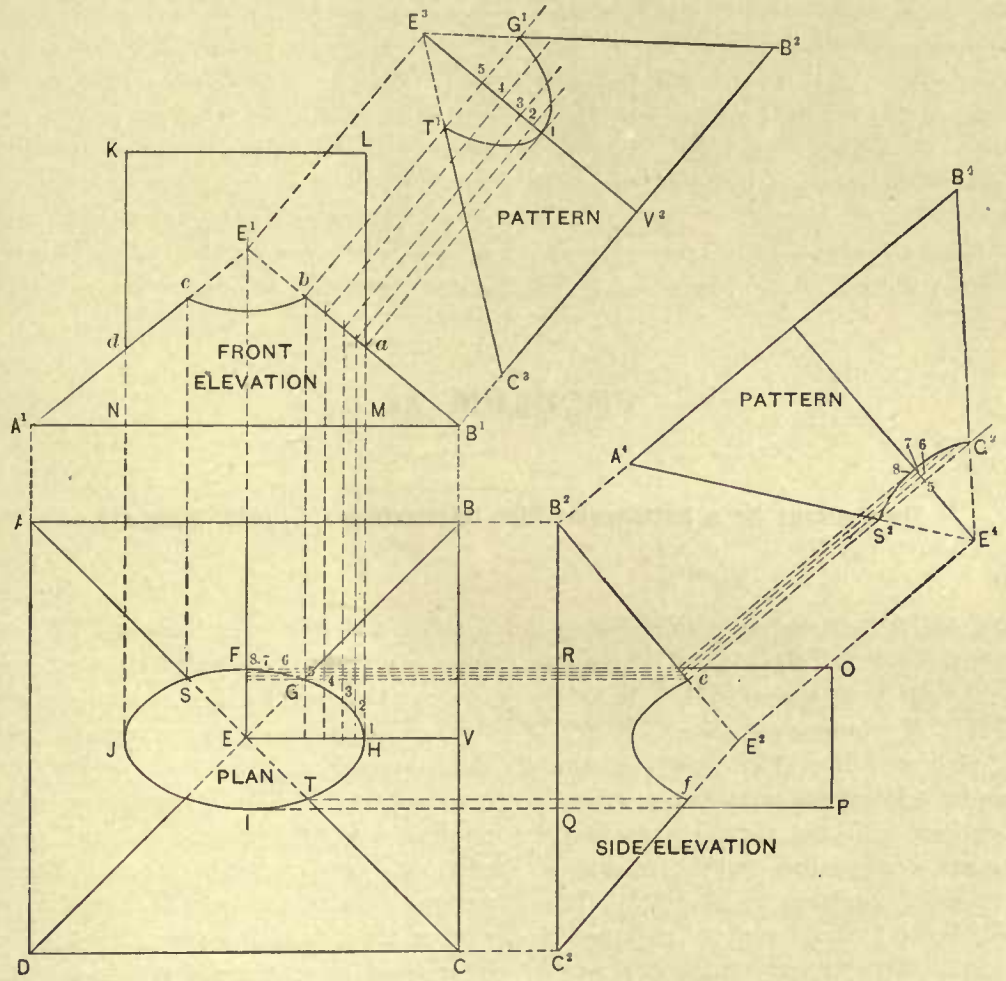


Fig. 334.—The Patterns for a Square Pyramid to Fit Against the Sides of an Elliptical Pipe.

ting that side in profile as shown from E^1 to B^1. At right angles to E^1 B^1 carry lines from each of the points indefinitely, as shown. At any convenient distance away, cut these lines by any line, as E^2 V^2, drawn parallel to E^1 B^1. Upon each of the lines drawn from the points in E^1 B^1, set off from E^2 V^2 the distances upon lines of corresponding number in the plan measured from E V. Thus upon line 5 of the pattern set off either way from its intersection with the line E^2 V^2 a length equal to the distance of point 5 of the plan from the line E V. Upon line 4 of the pattern set off distances equal to that of point 4 from E V of the plan, etc. Also make V^2 C^2 and V^2 B^2 equal to V C and V B of the plan. Lines drawn from C^2 and B^2 toward E^2 will meet the points previously set off on line 5 of the pattern, indicated by T^1 and G^1, and will constitute the sides or hips of the pattern, and a line traced through the points set off on lines 1 and 5 inclusive will give the shape of that portion of the pattern to fit against the pipe.

An exactly similar course is to be pursued in obtaining the pattern of the side of the pyramid A S G B (or A E B of the complete pyramid), whose profile is shown by B^2 E^2 of the side elevation, showing the narrow view of the pipe. The pattern is shown at A^4 B^4 G^2 S^2, and the operation is clearly indicated by the lines of projection.

If it is desired to complete the elevations by showing the lines of intersection of the sides of the pipe with the sides of the pyramid shown respectively in each elevation, as from *c* to *b* and *e* to *f*, it can be accomplished as follows: To obtain the line *c b*, erect lines vertically from points 6, 7 and 8 (not shown), passing through the space between *c* and *b* in the front elevation, upon each of which set off the hight of each point as measured upon lines of corresponding number from B^2 C^2 to B^2 E^2, as shown from R toward *e*, in the side elevation; then a line traced through the points thus obtained will give the line *c b*. In the same manner lines from the points 1, 2, 3 and 4 can be carried at right angles to B^2 C^2 into the side elevation, upon which to set off hights of corresponding points as measured from A^1 B^1 to B^1 E^1, as shown between *a* and *b* in the front elevation; then a line traced through the points will give the line *e f*.

PROBLEM 52.

The Patterns for a Rectangular Pipe Intersecting a Cylinder Obliquely.

In Fig. 335, let A B C represent the plan of a drum or cylinder, and B E D C the plan of rectangular pipe, the profile of which is shown by F G H I. In the elevation, J K L M represents the drum, N O P Q the rectangular pipe, and K *n* O the angle at which they are to intersect. Draw the end view, or plan, of circular drum in line with the elevation, as shown. Also extend O *n* and P *q* so a line dropped from point C of plan will cut them, as shown by N and Q. Then *n* N Q *q* is the joint between the drum and pipe, as shown in elevation. For the pattern of rectangular pipe proceed as follows: Divide B C of plan into any convenient number of equal parts, and from these points carry lines horizontally cutting E D. Also from the points in C B drop lines vertically cutting Q P and N O. On O P extended lay off a stretchout of profile F G H I, as shown by I I′, transferring the spaces in E D to H G and F I′, and through the points in it draw the usual measuring lines, as shown. Place the T-square parallel with the stretchout line I I′, and, bringing it successively against the points in the miter lines N *n* Q *q*, cut the corresponding measuring lines, as indicated by the dotted lines. Lines traced through the points thus obtained, as indicated by *i h g f i′*, will give the desired pattern. It will be observed that I H *h i* is a duplicate of O P Q N, and that G F *f g* is also a duplicate, only in a reversed position. The points in *h g* of pattern are derived from Q *q*, as the points in *f i′* of pattern are derived from N *n*. If the size of the work is such as to render it inconvenient to drop points from the elevation to the pattern by means of the T-square, the stretchout line I I′ can be drawn where convenient, the usual measuring lines erected and the distances from O P to points in N *n* and Q *q* transferred by means of the dividers to lines of similar number drawn from the stretchout line.

For the pattern or shape of opening in drum, proceed as follows: On L M extended, as R U, lay off a

stretchout of B C of plan, and from the points thus obtained erect the usual measuring lines, as shown. Place the T-square parallel with M L, and, bringing it successively against the points N *n* and Q *q*, cut measuring lines of corresponding number. Through the points thus obtained trace the lines V W and Y X; then V W X Y will be the shape of the required opening in the side of the drum.

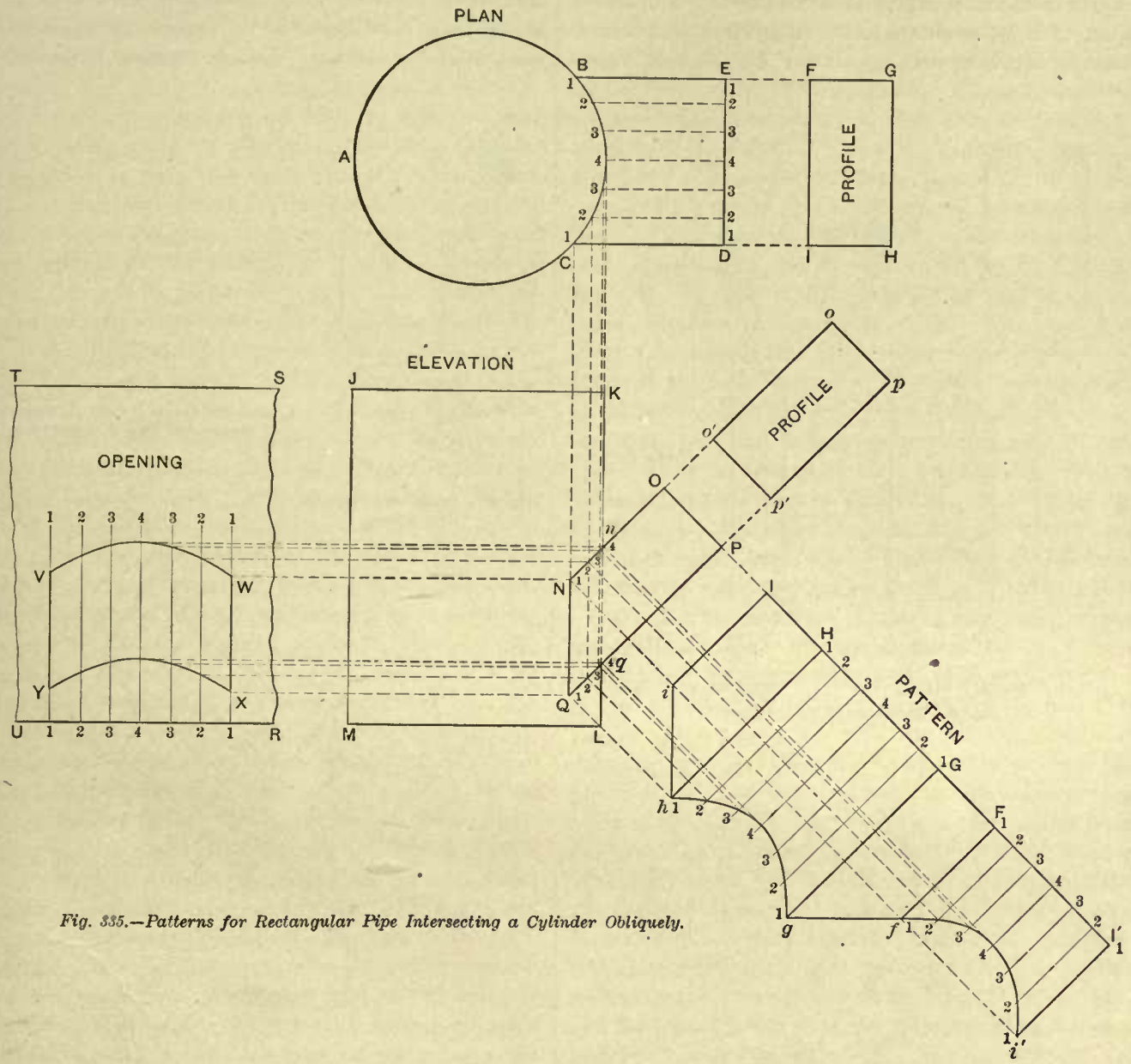


Fig. 335.—Patterns for Rectangular Pipe Intersecting a Cylinder Obliquely.

PROBLEM 53.

The Pattern for the Intermediate Piece of a Double Elbow Joining Two Other Pieces Not Lying in the Same Plane.

In Fig. 336 is shown a front and side view of a somewhat complicated arrangement of elbows such as sometimes occurs when pipes have to be carried around beams or through limited openings. An inspection of the drawing will show that once the correct angle of the different elbows is ascertained the development of the miters will be quite simple, and is the same as those occurring in several of the problems preceding

this. The lower section of the pipe rises vertically to the first elbow, B, from which it must be carried upward a distance equal to C M, to the left a distance equal to B M, as shown in the front view, and back a distance equal to *o* C, as shown by the side view. From the elbow C it then rises vertically, as seen in front, but really toward the observer as shown by the side view. The problem then really consists in finding the correct angles of the elbows, and becomes a question of draftsmanship rather than of pattern cutting. Some suggestions then with regard to the methods employed in drawing the two views shown in Fig. 336 will be of assistance to the pattern cutter. According to the principles of projection each individual point must appear at the same hight in both elevations, and at the same distance right or left and forward or back, with reference to the center lines of the plan. As front and side views are here required, begin by first placing the given plan in two positions, turning those sides of it to the bottom which correspond to the sides required in the elevations, and proceed by erecting the center lines of the differ-

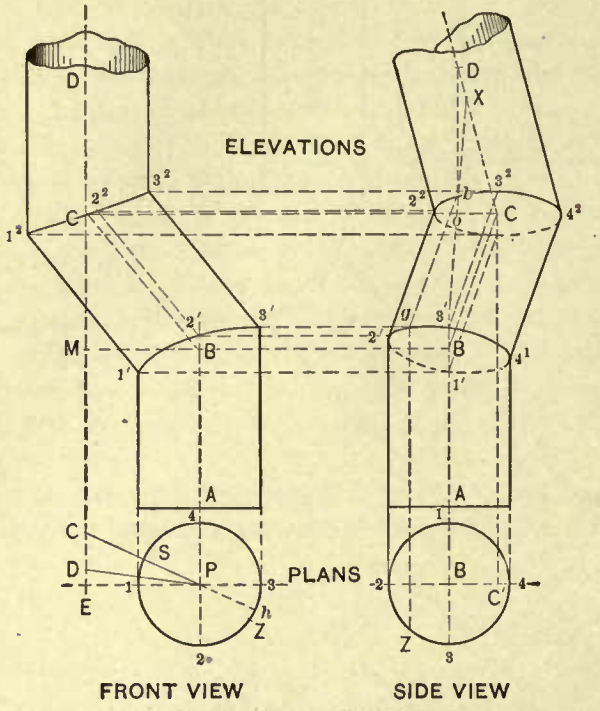


Fig. 336.—Elevations of Double Elbow.

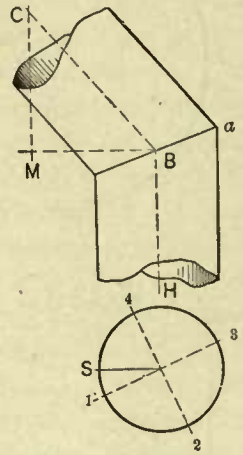


Fig. 337.—Correct Side View of Lower Elbow.

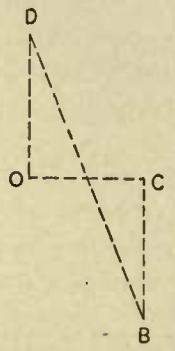


Fig. 338.—Diagram Used in Obtaining Correct Side View of Upper Elbow.

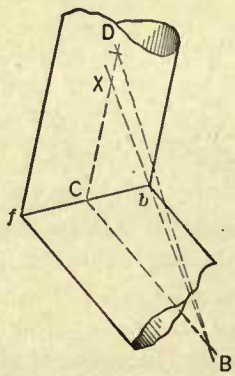


Fig. 339.—Correct Side View of Upper Elbow.

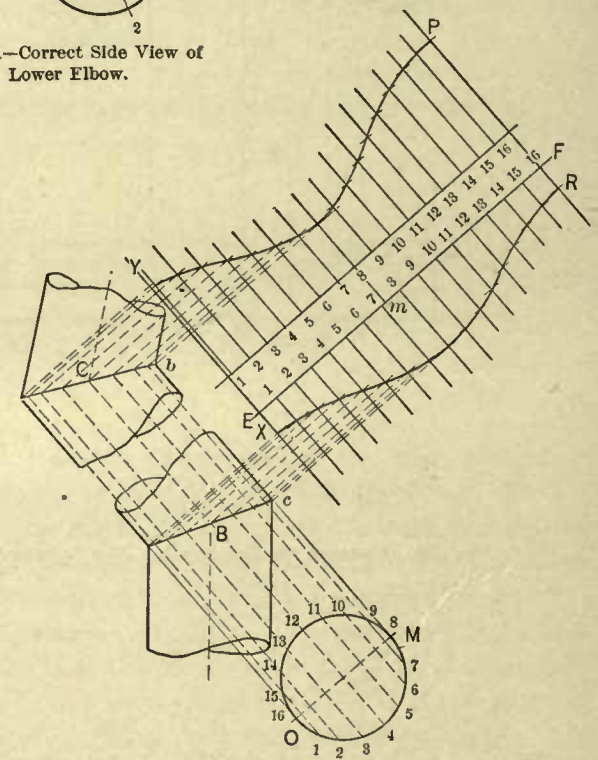


Fig. 340.—Method of Obtaining the Pattern of Middle Portion in One Piece.

The Pattern for the Intermediate Piece of a Double Elbow Joining Two Other Pieces Not Lying in the Same Plane.

ent pieces in their proper positions and building the pipe around them, so to speak. The plan being a circle, the different sides can only be indicated by numbering the points, as will be seen by referring to the plans, point 2 appearing in front in the front elevation, and point 3 appearing in front in the side elevation. The plans having been so arranged and corresponding parts in both given the same number, proceed now to erect the center line of the lower section, making the hight of the first bend, B, the same in both views, as indicated by the dotted horizontal line. From this point the center line is continued in both views, giving it its proper inclination to the left in the front view, and to the right in the side view, all according to the specified requirements, thus establishing the point C, making it agree in hight in both views. From this point the pipe appears inclined only in the side view, which means that it leans toward the observer in the front view. Next draw the outlines of the pipe at equal distances from the center line and on either side of it throughout the entire course of the pipe in both views, deriving them from the points of plans 1 and 3 in the front view and 2 and 4 in the side view. Their intersection in the front view will give definitely the positions in the miter of points $1'$, 1^2, and $3'$, 3^2, and in the side view of points $2'$, 2^2, and $4'$, 4^2. As point $3'$ has been established in the front view, if a line be carried horizontally across till it intersects the line from point 3 of the side view, it will give the hight of point $3'$ in the miter, as shown in the front view. In the same manner a horizontal line from $1'$ in front, intersecting the perpendicular from point 1 in plan of side, will give the true hight of point $1'$ in the side view. A careful inspection of the dotted lines of Fig. 336 will make the subsequent operations necessary to the completion of the elevations clear to the reader without further explanation. Since neither of the views gives a true side view of the intermediate piece, one must be constructed from the facts now known, so as to get the true angle of the elbow B. By dropping a vertical line from the point C of the front view into the plan it will appear that the horizontal distance between the points C and B would be measured by the line E P of the plan; but by further reference to the side elevation the position of the point C is found to be to the right of its center line by a distance equal to B C' of the plan; therefore, if this distance be set off on the vertical line from the point E in the plan below the front view, which is indicated by E C, the point C will determine the true position in the plan of the point C of the elevations, and the distance C P will be its horizontal distance from B. Since, now, its vertical distance can easily be obtained from either front or side elevation, a new diagram can now be easily constructed which shall contain the proper dimensions to obtain a correct side view of this elbow. Proceed, then, to construct diagrams shown in Fig. 337, making C M equal to C M, Fig. 336, M B equal to C P of the plan, Fig. 336; a line connecting the points C and B will represent the center line of the intermediate portion of the pipe and give its true relation to the vertical portion whose center line is represented by B H, Fig. 337. By drawing the outlines of the pipe at the required distance on either side of the center lines B H and B C, a correct side view of the miter is obtained. Since, as has been referred to above, the upper portion of the pipe appears vertical in one view and inclined in the other (see Fig. 336), a correct side view of the upper elbow is more difficult to be obtained. While different methods may be devised for obtaining it, the following is perhaps the simplest: As the upper section of the pipe, as shown by Fig. 336, is of indefinite length, any point may be assumed, as D, from which to take measurement for obtaining the angle of the upper elbow. Since the true length of the line C B of either elevation has already been obtained and given in Fig. 337, and since the true length of the part C D can be derived from the side view of Fig. 336, it is necessary only to obtain the true distance between the points D and B of the elevations to obtain the proper angle at the point C. By dropping a vertical line from the point D to a horizontal line drawn from the point C in the side view, Fig. 336, the horizontal distance between C and D may be obtained. By tranferring this distance, *o* C, to the plan of the front view, and locating its distance from C, as indicated by D, this point will give the true position of the point D in the plan, and the line D P will give the true horizontal distance between the points D and B. In Fig. 338 let the distance O C be equal to the line D P of Fig. 336. At point O erect a perpendicular, O D, making the distance O D equal to *o* D of the side elevation, Fig. 336. From the point C drop a perpendicular, C B, making that distance equal to the vertical hight between the points C and B, as measured on line C M of the front view; a diagonal line connecting the points D and B will readily be seen to give the true distance between the points bearing those letters in Fig. 336. Proceed now to construct the triangle shown in Fig. 339, making C B equal to C B of Fig. 337. From C as a center,

with a radius equal to C D as obtained from the side view in Fig. 336, draw a small arc, which intersect with the arc drawn from the point B, with a radius equal to B D as obtained in Fig. 338; this will give the correct angle of the upper elbow at C. A complete view of the miter may be obtained by further adding outlines of the pipe at equal distances on either side of the center lines, and connecting their angles, as shown by the line *b f*. Having now obtained two correct side views of the two elbows, the problem of obtaining the patterns for the same can be solved by the regular method.

To obtain the pattern for the middle portion in one piece further calculations, however, will be required. This, of course, could be obviated by making a slip joint in the middle portion of the pipe, by means of which the two elbows could be made separate, and then simply turned upon each other till the required angle is obtained. But as it might be desirable to make the pattern of the middle portion in one piece some means must be employed of ascertaining just how far one elbow would have to be turned upon the other were they made separately. As the seam in pipe containing elbows is usually made at either the shortest or the longest point of the miter, it may be easily seen, by an inspection of Fig. 336, that a line from the shortest point, or throat, *b* of the upper miter of the piece in question, would not meet the longest point, or point *a*, Fig. 337, in the miter of the other end, and some means must be devised for obtaining the real position of these points, of which the following is perhaps the simplest: From either of the points D or B, Fig. 339, draw a line through the point *b*, continuing it to the further side of the triangle, as indicated by the line B X. Lay off the distance D X upon the line D C of the side view, Fig. 336, thereby locating the position of the point *x* in that view. A line connecting this point with point B must intersect the miter line 2^2, 4^2, in this view at the same point which it does in Fig. 339, thereby locating its position just as much as in Fig. 339. This point having been obtained, its equivalent upon the lower miter may be found by means of a line drawn parallel to the center line of the middle portion, intersecting it at the point *g*, from which point it can be carried vertically to the plan, as shown by Z, where its distance from other points can be measured with accuracy. The position of the point *a* in Fig. 337 will readily be seen to be at point *h* in the plan of the front view, Fig. 336. By transferring the point Z from the plan of the side view to the plan of the front view, which can be done by measuring its distance from either of the points 2 or 3, the relative position of the points *h* and Z upon the same circle will be apparent. Fig. 340 shows a diagram, in which a correct side view of the two elbows is shown, giving the proper distance between the points B and C. Considering the lower one to be in its proper and fixed position, the profile is constructed and divided into points for the purpose of obtaining a stretchout and the miter pattern according to the usual method, the stretchout being shown upon the line E F in the profile and point 8 will readily be seen to correspond with point *h* in the plan of the front view. The position of the point Z in the same plan can be obtained by measuring its distance from point *h* and transferring it to Fig. 340, as indicated by M. As the point *b* of the upper elbow is in relation to the highest point, or *a*, of the lower elbow as the point M is to the point 8 in the profile, it becomes necessary to place the point 8 in the stretchout of the upper elbow as far from the point 8 on the stretchout of the lower one as the distance from 8 to M in the profile, which is shown by *m* in the stretchout. The stretchout of the upper elbow is thus moved, as it were, in its relation to the stretchout of the lower elbow, that portion of it which extends beyond the point 1 at the left end being added to the other so as to make the seam continuous. The points are then dropped from the profile to the two miter lines, and thence into measuring lines of corresponding number in the stretchout. Lines traced through the points of intersection, as shown by Y P R X, will be the required pattern. The miters for the upper and lower sections would, of course, be inverted duplicates of the adjacent ends of the middle piece.

PROBLEM 54.

A Joint Between Two Pipes of the Same Diameter at Other Than Right Angles.

Let L F D E K I H M of Fig. 341 represent the elevation of two pipes of the same diameter meeting at the angle M H I, for which patterns are required. Draw the profile or section A' B' C' in line with the branch pipe, and the section A B C in line with the main pipe. As both pipes are of the same diameter, and the end of one piece comes against the side of the other piece, both halves of the branch pipe (dividing at the point B) will miter with one-half, B D, of the main pipe. By projecting lines through the elevations of each piece from the points B or 4 of their respective profiles the point G is obtained, which, being connected with points F and H, gives the required miter line. Space both the profiles into the same number of equal divisions, commencing at the same point in each. For the pattern of the arm proceed as follows: Lay off the stretchout O N opposite the end of the arm and draw the usual measuring lines at right angles through it, as shown. Place the T-square at right angles with the arm, or, what is the same, parallel with the stretchout line, and, bringing the blade successively against the points in the miter line F G H, cut the corresponding measuring lines. Through the points thus obtained trace the line P R S T, which will form the end of the pattern required. For the pattern of the main pipe proceed as follows: Opposite one end lay off the stretchout, as shown by V Y, and opposite the other end lay off a corresponding line, as shown by U X. Connect U V and X Y. From so many of the points in the stretchout line V Y as represent points in the half of the profile B A D draw the usual measuring lines. With the T-square placed parallel to the molding D I, drop the points from the profile onto the miter line F G H; then, placing it at right angles to the molding, drop lines from the points in the miter line intersecting the corresponding measuring lines. A line traced through these points of intersection, as F' Z H' W, will describe the shape required. The position of the seam in both the arm and the main pipe is determined by the manner of numbering the spaces in the stretchout. In the illustration the seam in the arm is located in the shortest part, or at a point corresponding to 1 of the profile. Accordingly, in numbering the divisions of the stretchout, that number is placed first. In like manner the seam in the main pipe is located at a point opposite the arm. Therefore, in

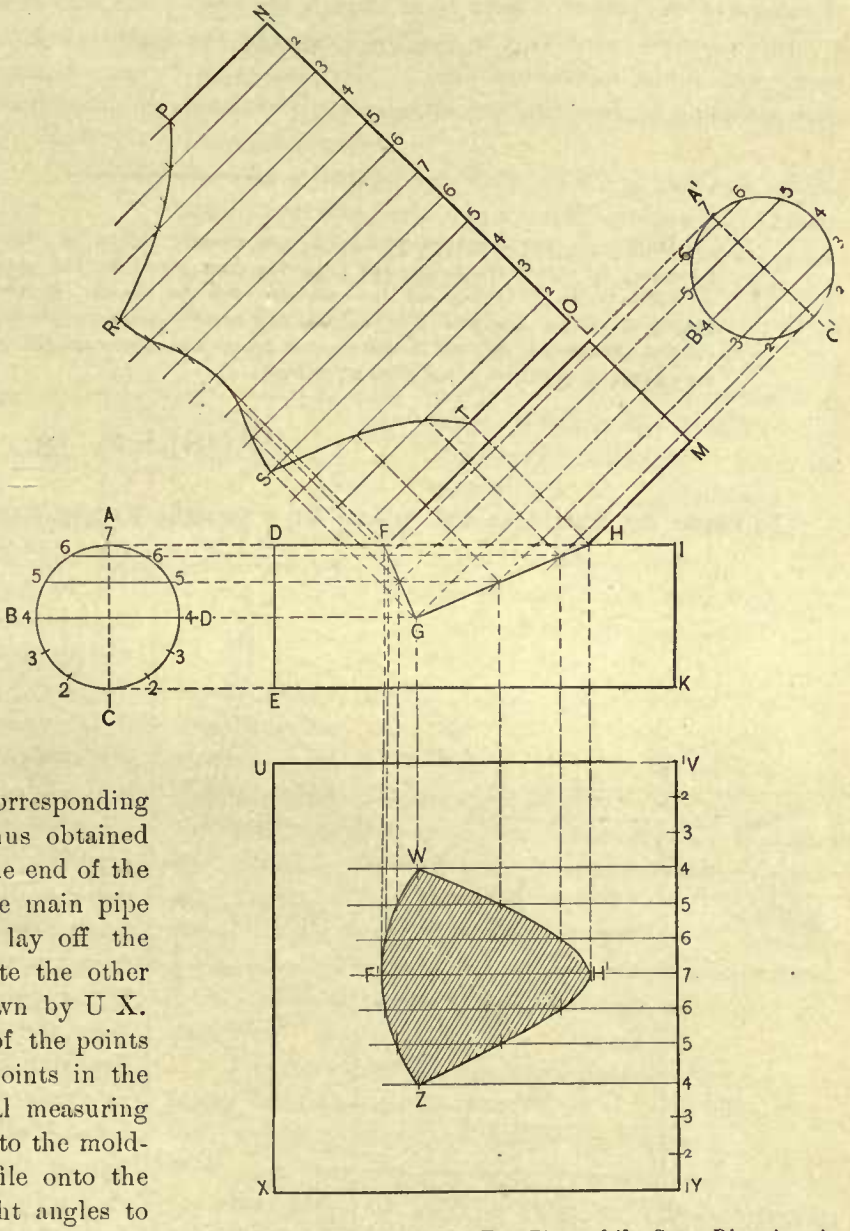


Fig. 341.—A Joint between Two Pipes of the Same Diameter at Other than Right Angles.

numbering the spaces in the stretchout commence at 1, which, as will be seen by the profile, represents the part named. If it were desirable to make the seam come on the opposite side of the main pipe from where it has been located—that is, come directly through the opening made to receive the arm—the numbering of the stretchout would have been begun with 7. In that case the opening F' W H' Z would appear in two halves, and the shape of the pattern would be as though the present pattern were cut in two on the line 7 and the two pieces were joined together on lines 1. By this explanation it will be seen that the seams may be located during the operation of describing the pattern wherever desired. It is not necessary, as prescribed at the outset of this problem, that both profiles should be spaced off exactly alike. Any set of spaces will answer quite as well, provided there be points in each exactly half way between A and B of either profile—that is, where points 4 are now located. They are spaced alike in this case to show that lines dropped from points of the same number in each profile arrive at the same point on the miter line, and that therefore when both pipes are the same diameter and their axes intersect, one profile may be used for the entire operation.

Note.—In the nineteen problems immediately following, the conditions are such that it will be necessary to obtain the miter line from the data given by the operation of raking before the straightforward work of laying out the patterns can be begun. However, as certain parts of the work of raking the miter line and of laying out the pattern are common to both operations, the two are usually carried along together, and therefore such points and spaces should be assumed upon the profiles at the outset as will be required in the final stretchout.

PROBLEM 55.

To Obtain the Miter Line and Pattern for a Straight Molding Meeting a Curved Molding of Same Profile.

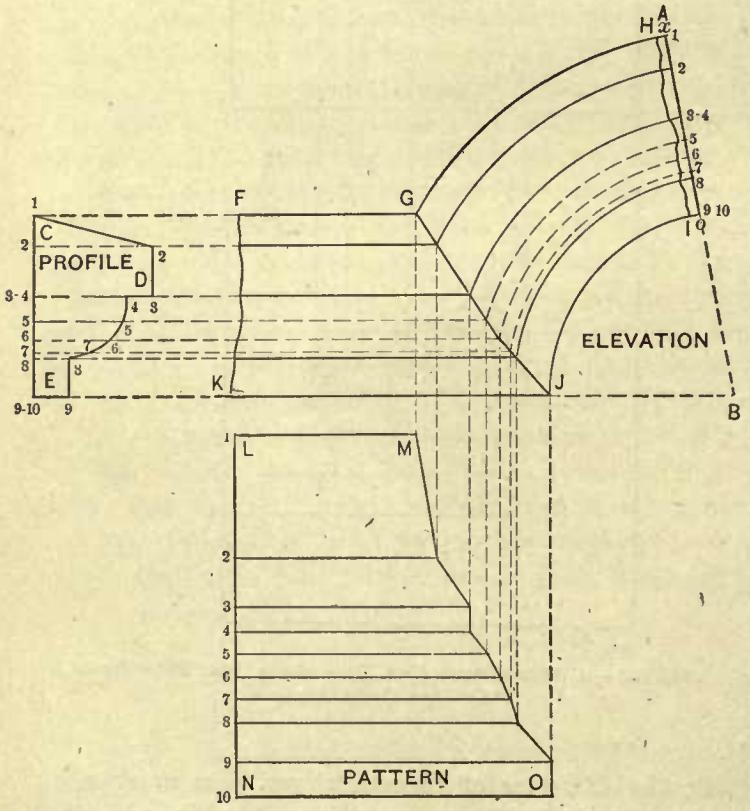


Fig. 342.—The Miter Line between a Curved and a Straight Molding of the Same Profile.

In Fig. 342, let F G J K represent a piece of straight molding joining a curved mold, G H I J, the profiles of the straight and curved molding being the same. To obtain the miter line or line of joint, G J, proceed as follows: Draw the profile in line with the straight molding, as shown by C D E, and divide into any convenient number of parts. From the divisions in the profile draw lines parallel to F G in the direction of the miter indefinitely, and also in the opposite direction, cutting the vertical line C E of the profile, as shown by the small figures, which correspond in number to the divisions on the profile. From B, the center from which the curved molding is struck, draw the line B A through the molding, as shown. Transfer the hights of the various points of the profile as obtained on the line C E to the line A B, placing the point E at the point *o* of the intersection of the lower line of the curved molding with the line A B, all as shown by X *o*. Then, with B as a center, draw arcs from the divisions on the line X *o*, intersecting lines of corresponding numbers drawn from the profile parallel to the lines of the straight molding. A line traced through these intersections, as shown by G J, will be the required miter line, and, as will be seen, is not a straight line. To obtain the pattern for the

straight molding, draw the line L N at right angles to it, upon which place the stretchout of the profile C D E, as shown by the small figures. At right angles to the stretchout line L N, and through the points in it, draw the usual measuring lines. With the T-square placed at right angles to K J, bring it successively against the points forming the miter line G J, and cut lines of corresponding number in the stretchout. Then a line traced through these points of intersection will form the miter end of the pattern shown by L M N O. The methods employed in obtaining the patterns for the curved portions are treated in Section 2 of this chapter.

PROBLEM 56.

A T-Joint Between Pipes of Different Diameters.

In Fig. 343 it is required to make a joint at right angles between the smaller pipe D F G E and the larger pipe H K L I. For this purpose both a side and an end view are necessary. As the two pieces forming the T are of different sections this problem really consists of two separate operations, but as certain steps can be used in both operations the following course will be most economical.

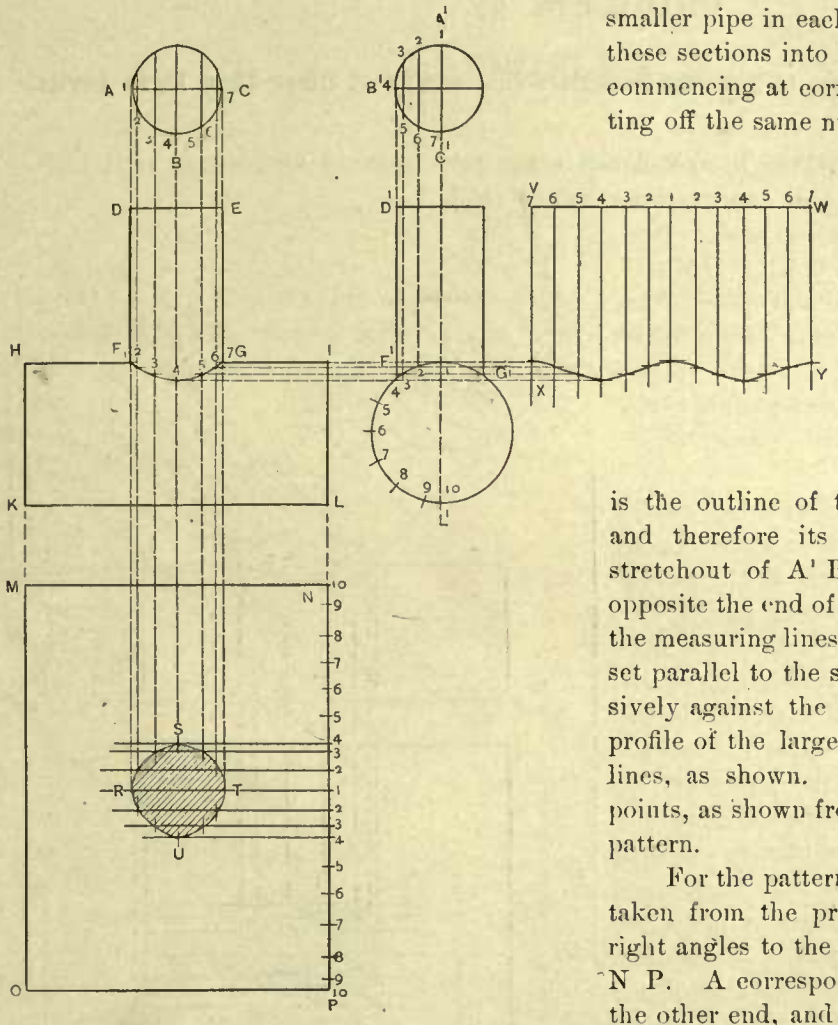


Fig. 343.—A T-Joint between Pipes of Different Diameters.

At a convenient distance from the end of the smaller pipe in each view draw a section of it. Space these sections into any suitable number of equal parts, commencing at corresponding points in each, and setting off the same number of spaces, all as shown by A B C and A' B' C'. From the points in A B C draw lines downward through the body of the large pipe indefinitely. From the points in A' B' C' drop point onto the profile of the large pipe, as shown by the dotted lines. For the pattern of the smaller pipe the requirements are its profile A B' C' and the line F' G', which is the outline of the surface against which it miters, and therefore its miter line. Therefore, take the stretchout of A' B' C' and lay it off at right angles opposite the end of the pipe, as shown by V W. Draw the measuring lines, as shown. Then, with the T-square set parallel to the stretchout line, and brought successively against the points between F' and G' upon the profile of the large pipe, cut corresponding measuring lines, as shown. Then a line traced through these points, as shown from X to Y, will form the end of the pattern.

For the pattern of the larger pipe the stretchout is taken from the profile view F' G' L' and laid off at right angles to the pipe opposite one end, as shown by N P. A corresponding line, M O, is drawn opposite the other end, and the connecting lines M N and O P are drawn, thus completing the boundary of the piece through which an opening must be cut to meet or miter with the end of the smaller pipe. According to the rule given in Chapter V, a profile and a miter line are necessary. The profile F' G' L' has already been stated, but no line has yet been drawn in the elevation

of the larger pipe which shows its connection with the smaller pipe. This can only be found by projecting lines from the points dropped upon F' G' through the elevation till they intersect with lines previously drawn from the profile A B C, as shown between F and G. F G then constitutes the miter line. For economy's sake, then, the spaces 1 to 4 previously obtained in the profile are duplicated upon the stretchout, as shown, to which are added as many more (4 to 10) as are necessary. As the points 1 to 4 have already been dropped upon the miter line in its development it is now only necessary to drop them parallel to the stretchout line into measuring lines of corresponding number, when a line traced through the points of intersection, as shown by R S T U, will give the pattern of the opening required.

It may be noticed that the development of the miter line F G is not really necessary in this case, as the points are really dropped from the profile A B C right. through the elevation till they intersect the measuring lines. This happens in consequence of the arm or smaller pipe being at right angles to the larger one. Different conditions are shown in Problems 57 and 58 following.

PROBLEM 57.

The Joint Between Two Pipes of Different Diameters Intersecting at Other Than Right Angles.

Let A B C, Fig. 344, be the size of the smaller pipe, and Y N' Z the size of the larger pipe, and let H L M be the angle at which they are to meet. Draw an elevation of the pipes, as shown by G K I O N M L H, placing the profile of the smaller pipe above and in line with it, as shown, also placing a profile of the larger pipe in line with its elevation, as shown. In this problem the profiles of the moldings or pipes are given, but the line representing their junction must be obtained before going ahead.

To obtain this miter line, first place a duplicate of the profile of the smaller pipe in position above the end view of the larger pipe, as shown by A' B' C', the centers of both being on the same vertical line, C' N'. Divide both profiles of the small pipe into the same number of spaces, commencing at the same point in each. From the points in A B C project lines indefinitely through the elevation of the arm, as shown. From the points in A' B' C' drop lines on to the profile of the large pipe, and from the points there obtained carry lines across to the left, producing them until they intersect corresponding lines in the elevation. A line traced through these several points of intersection gives the miter line K L, from which the points in the two patterns are to be obtained. For the pattern of the small pipe proceed as follows: Opposite the end lay off a stretchout, at right angles to it, as shown by E F. Through the points in it draw the usual measuring lines, as shown. In the developing of the line K L the points have already been dropped upon the miter line. It therefore only remains to carry them into the stretchout, which is done by placing the -square at

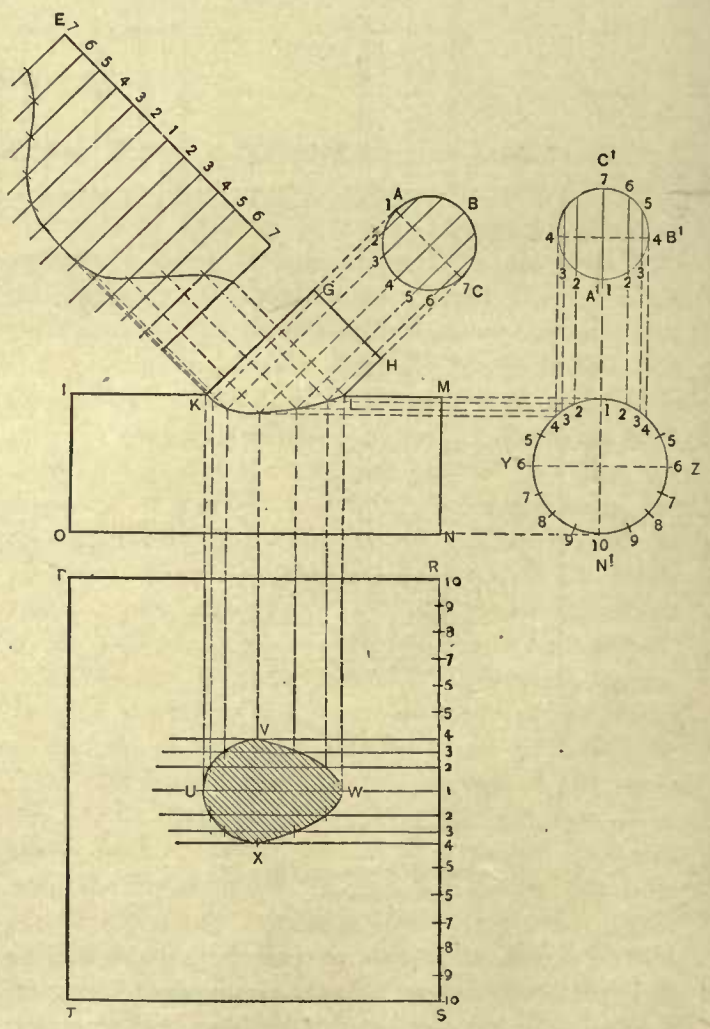


Fig. 344.—The Joint between Two Pipes of Different Diameters Intersecting at Other than Right Angles.

right angles with the pipe, and, bringing it successively against the points in the miter line K L, cut the corresponding measuring lines, as shown by the dotted lines. A line traced through the points thus obtained will give the pattern of the end of the arm, as indicated.

For the pattern of the large pipe proceed as follows: Opposite one end, and at right angles to it, lay off a stretchout line, as shown by R S In spacing off this stretchout it is best to transfer the spaces from 4 to 4 as they exist, as by so doing measuring lines will result which will correspond with points already existing in the miter line K L, thereby saving labor, as in the case of the smaller pipe, and also avoiding confusion. The other points in the profile are taken at convenience, simply for stretchout purposes. Draw a corresponding line, P T, opposite the other end, and connect P R and T S. In laying off the stretchout R S, that number is placed first which represents the point at which it is desired the seam shall come. For the shape of the opening in the pattern, draw measuring lines from the points 4, 3, 2, 1, 2, 3, 4, as shown, and intersect them by lines dropped from corresponding points in the miter line. Through the points thus obtained trace the line U V W X, which will represent the shape of the opening required.

PROBLEM 58.

The Joint Between an Elliptical Pipe and a Round Pipe of Larger Diameter at Other Than Right Angles.—Two Cases.

In Fig. 345 J K L M is the side elevation of the round pipe and E F G H that of the elliptical pipe joining the larger pipe at the angle F G J. In the end elevation T S I shows the profile of the round pipe and U R S T the intersection of the elliptical pipe whose profile is shown at A B C D and N O P Q, respectively, in the side and end views. From an inspection of the drawings it will be seen that the side elevation shows the narrow view of the elliptical pipe, while the end elevation shows its broad view, or in other words, that the profile of the elliptical pipe is so placed that its *major* axis crosses the round or larger pipe. In Fig. 346 the elevations show the same pipes intersecting at the same angle, but with the difference that the profile of the elliptical pipe is so placed that its *minor* axis crosses the round pipe. The reference letters and figures are the same in the two drawings and the following demonstration will apply equally well to either:

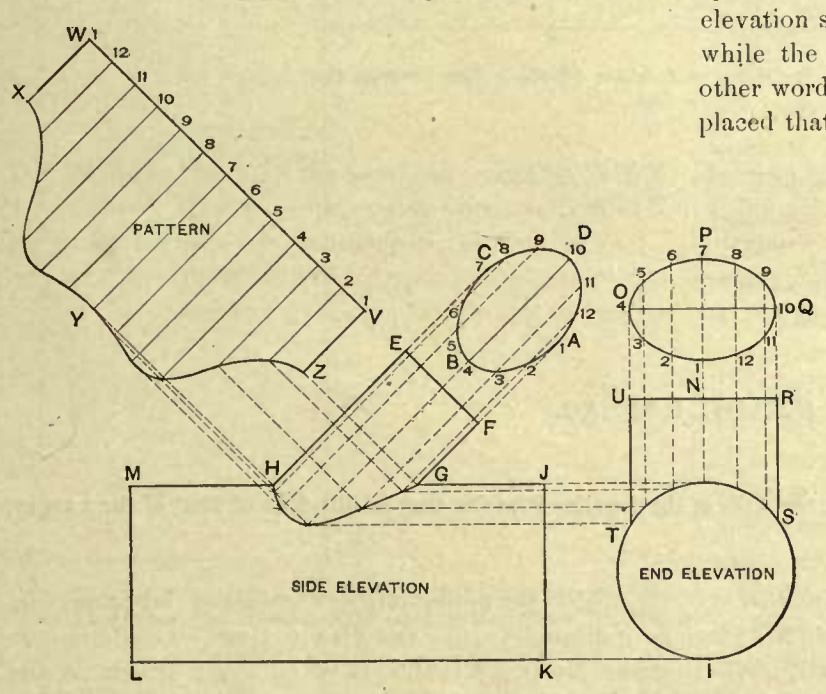


Fig. 345.—The Joint between an Elliptical Pipe and a Round Pipe of Larger Diameter at Other than Right Angles. First Case. The Major Axis of the Elliptical Pipe Crossing the Round Pipe.

By way of getting ready to lay out the miter, it will first be necessary to obtain a correct elevation of the miter line or intersection between the two pipes, as shown, from H to G. To do this divide the two profiles A B C D and N O P Q into the same number of equal parts, commencing at the same points in each. Draw lines from the points in N O P Q, parallel with U T, cutting T S. In a similar manner draw lines indefinitely from the points in A B C D, parallel with

H E, as shown. From the points in T S draw lines parallel with M J, which produce until corresponding lines from the two profiles intersect. Through the several points of intersection thus obtained draw the miter line H G. For the pattern of E F G H proceed as follows: On E F extended, as V W, lay off a stretchout of profile A B C D, through the points in which draw the usual measuring lines at right angles to the stretchout line. With the T-square placed at right angles with H E, or parallel with V W, and brought successively against the points in the miter line H G, cut corresponding measuring lines. A line traced through the points thus obtained, as shown by X Y Z, will give the miter cut required, and V W X Y Z shows the entire pattern.

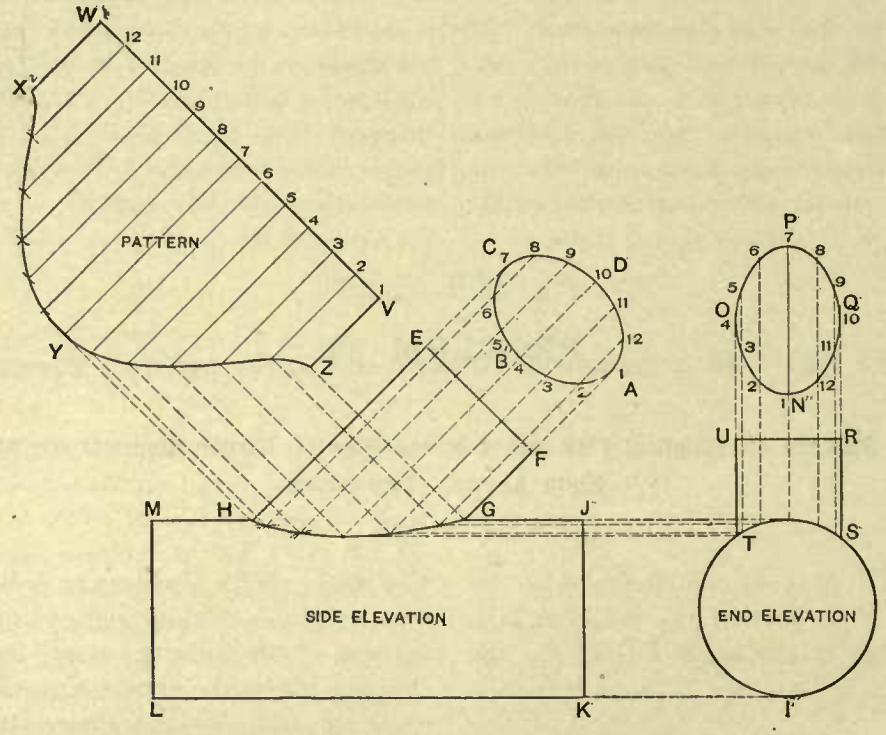


Fig. 346.—Second Case. The Minor Axis of the Elliptical Pipe Crossing the Round Pipe.

The method of obtaining the shape of the opening in the round pipe is exactly similar to that described in the several preceding problems.

PROBLEM 59.

A T-Joint Between Pipes of Different Diameters, the Axis of the Smaller Pipe Passing to One Side of That of the Larger.

The principle here involved and the method of procedure are exactly the same as in Problem 56, but the whole of the profiles must be used instead of the halves, because the two axes or center lines of the pipes do not intersect.

In Fig. 347, let A B C be the size of the small pipe and F' H' M' be the size of the large pipe, between which a right-angled joint is to be made, the smaller pipe being set to one side of the axis of the large pipe, as indicated in the end view. Draw an elevation, as shown by D F I L M K G E. Place a profile of the small pipe above each, as shown by A B C and A' B' C', both of which divide into the same number of equal parts, commencing at the same point in each. Place the T-square parallel to the small pipe, and, bringing it successively against the points in the profile A' B'

C', drop lines cutting the profile of the large pipe, as shown, from F' to H'; and in like manner drop lines from the points in the profile A B C, continuing them through the elevation of the larger pipe indefinitely. For the pattern of the small pipe set off a stretchout

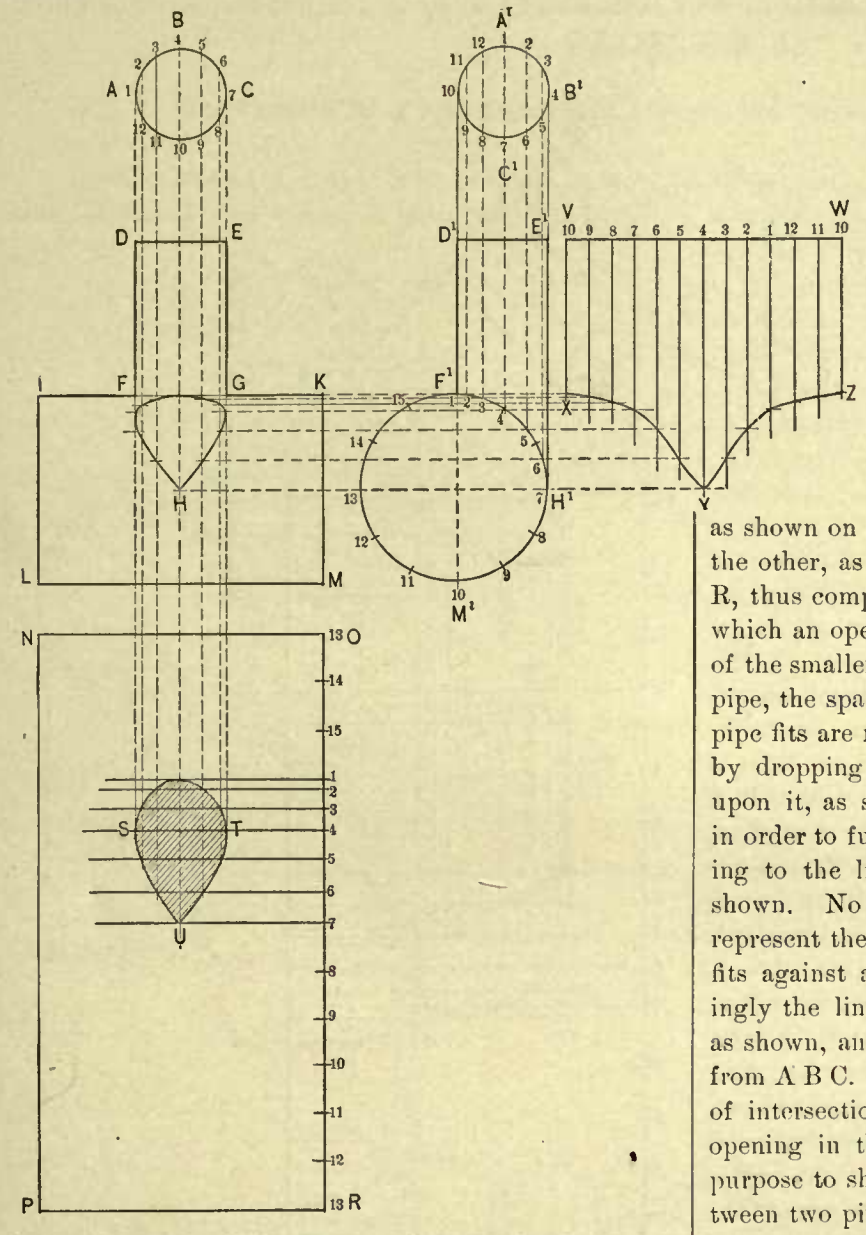


Fig. 347.—A T-Joint between Pipes of Different Diameters, the Axis of the Smaller Pipe Passing to One Side of that of the Larger.

line, V W, at right angles to and opposite the end of the pipe, and draw the measuring lines, as shown. These measuring lines are to be numbered to correspond to the spaces in the profile, but the place of beginning determines the position of the seam in the pipe. In the illustration given the seam has been located at the shortest part of the pipe, or, in other words, at the line corresponding to the point 10 in the section. Therefore commence numbering the stretchout lines with 10. Place the T-square at right angles to the small pipe, and, bringing the blade successively against the points in the profile of the large pipe from F' to H', cut the corresponding measuring lines, as shown. A line traced through the points thus obtained, as shown by X Y Z, will form the end of the required pattern.

For the pattern of the large pipe, lay off a stretchout from the profile shown in the end view, beginning the same at whatever point it is desired to locate the seam, which in the present instance will be assumed on a line corresponding to point 13 in the profile. After laying off the stretchout opposite one end of the pipe, as shown on O R, draw a corresponding line opposite the other, as shown by N P, and connect N O and P R, thus completing the outline of the pattern, through which an opening must be cut to miter with the end of the smaller pipe. In spacing the profile of the large pipe, the spaces in that portion against which the small pipe fits are made to correspond to the points obtained by dropping lines from the profile of the small pipe upon it, as shown by 1 to 7 inclusive. This is done in order to furnish points in the stretchout corresponding to the lines dropped from the profile A B C, as shown. No other measuring lines than those which represent the portion of the pipe which the small pipe fits against are required in the stretchout. Accordingly the lines 1 to 7 inclusive are drawn from O R, as shown, and are cut by corresponding lines dropped from A B C. A line traced through the several points of intersection gives the shape S T U, which is the opening in the large pipe. If it be necessary for any purpose to show a correct elevation of the junction between two pipes, the miter line F H G is obtained by intersecting the lines dropped from A B C with corresponding lines carried across from the same points obtained on the profile F' H', by dropping from A' B' C', explained in Problems 56, 57 and 58, and all as shown by the dotted lines.

As remarked in Problem 56, this line is not absolutely necessary, but is of great advantage in illustrating the nature and principles of the work to be done.

PROBLEM 60.

A Joint at Other Than Right Angles Between Two Pipes of Different Diameters, the Axis of the Smaller Pipe Being Placed to One Side of That of the Larger One.

In Fig. 348, let C' B' A' be the size of the smaller pipe, and D' E' I' the size of the larger pipe, between which a joint is required at an angle represented by W F K, the smaller pipe to be placed to the side of the larger. Draw an elevation of the pipes joined, as shown by V D G H I K F W. As in the preceding problems, the miter line or line giving a correct elevation of the junction of the pipes must be developed before the actual work of laying out the miter patterns can be begun, therefore place a profile or section of the arm in line with it, as shown by C' B' A', and opposite and in line with the end of the main pipe draw a section of it, as shown by D' E' I'. Directly above this section draw a second profile of the small pipe, as shown by C B A, placing the center of it in the required position relative to the center of the profile of the large pipe. Divide the two profiles of the small pipe into the same number of equal spaces, commencing at the same point in each. From the divisions in C' B' A' drop lines parallel to the lines of the arm indefinitely. From the divisions in C B A drop lines until they cut the profile of the large pipe, as shown by the points in the arc D' E'. From these points carry lines horizontally to the left, producing them until they intersect the corresponding lines from C' B' A'. A line traced through these points of intersection, as shown by D E F, will be the miter line between the two pipes. For the pattern of the arm proceed as follows: Lay off a stretchout at right angles to and opposite the end of the arm, as shown by R P, and through the points in it draw the usual measuring lines. Place the T-square at right angles to the arm, and, bringing it successively against the points already in the miter line, cut the corresponding measuring lines. A line traced through these points, as shown by U T S, will form the required pattern.

For the pattern of the main pipe draw a stretchout line opposite one end of it, as shown by M O, numbering the divisions in it with reference to locating the seam, which can be placed at any point desired. The spaces of the profile between D' and E' should be transferred to the stretchout point by point as they occur, as by so doing measuring lines will be

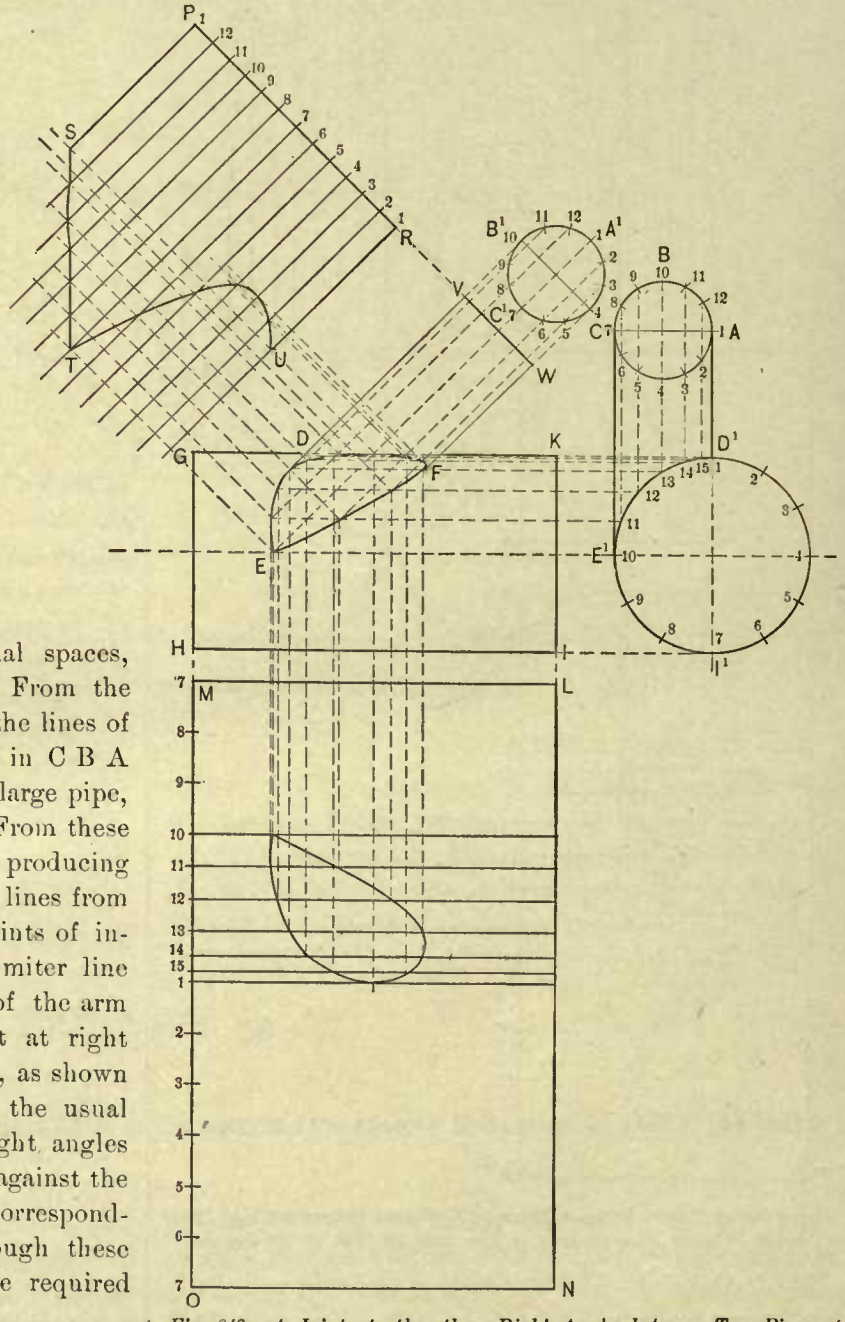


Fig. 348.—A Joint at other than Right Angles between Two Pipes of Different Diameters, the Axis of the Smaller Pipe being Placed to One Side of that of the Larger One.

obtained which will correspond to the points already in the miter line. Draw a line corresponding to the

stretchout line opposite the other end of the pipe, as shown by L N, and connect L M and N O. Through the points in the stretchout line corresponding to the points between D' and E' of the profile draw measuring lines, as shown by 10, 11, 12, 13, 14, 15 and 1. Place the T-square at right angles to the main pipe, and, bringing the blade against the points in D E F successively, cut the measuring lines of corresponding number, all as shown by the dotted lines. A line traced through these points of intersection, as shown near the middle of M L N O, will give the shape of the opening to be cut in the pattern of the main pipe.

PROBLEM 61.

The Patterns for a Pipe Intersecting a Four-Piece Elbow Through One of the Miters.

In Fig. 349, let A B C D E E' D' C' B' A' represent the four-pieced elbow in elevation, F G H J its profile, and K L M N the elevation of the pipe which intersects the elbow through a miter joint. In line with the pipe draw the profile of same, as indicated by O P R S. Extend F H of the profile of elbow, upon which as a center line draw another profile of the small pipe, as shown by O' P' R' S'. Divide both profiles of the small pipe into the same number of parts, commencing at the same points in each, as S and S'. Now parallel to F P' of the profile draw lines from the points in O' P' R' S' interseeting the profile F G H J, as shown.

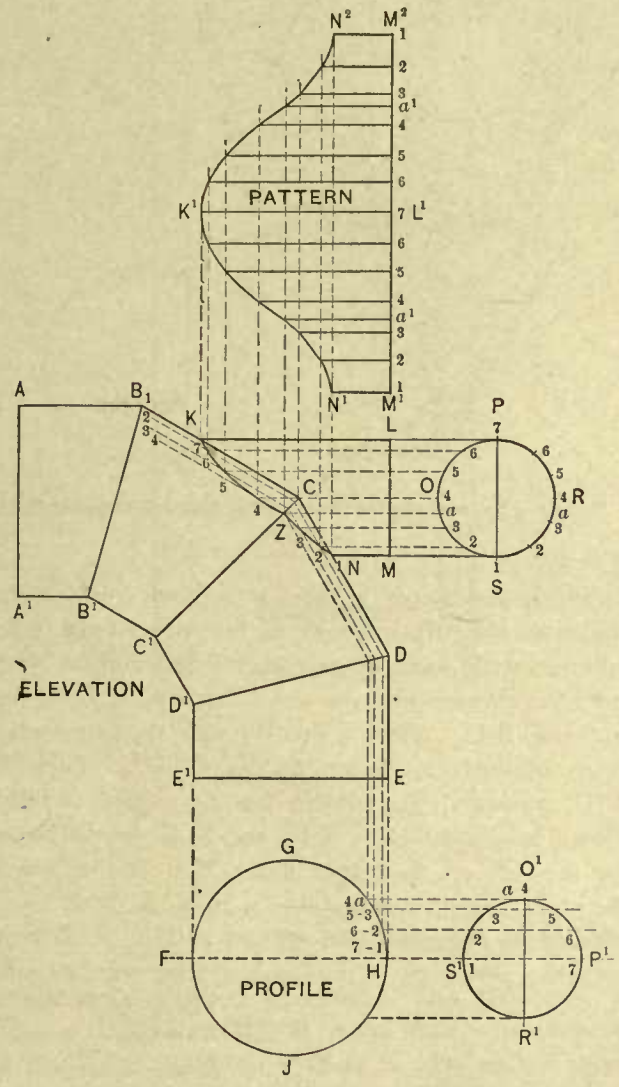


Fig. 349.—Pattern for the Pipe Intersecting an Elbow Through One of the Miters.

A profile should properly be drawn in its correct relation to the part of which it is the section. As the part C D D' C' is about to be considered first, the profile should be placed with its center line F H at right angles to C D; but as in a regular elbow of any number of pieces the miter lines all bear the same angle with the sides of the adjacent pieces, the profile may for convenience be placed in proper relation to one of the end pieces, after which lines may be carried from it parallel to the side it represents to the miter line, thence from one miter line to another, always keeping parallel to the side, continuing this throughout the entire elbow if necessary. Therefore parallel to D E of the elevation draw lines from the points in G H of the profile, cutting the miter line D' D, and continue these lines parallel to D C and C B. From the points in the profile O P R S draw lines parallel with L K interseeting lines of corresponding numbers drawn from G H. A line traced through these intersections will give the miter line K Z N. From the point Z in the miter line carry a line back to the profile of the pipe, as indicated by Z *a*. This gives, upon the profile of the pipe, the point at which the miter line K N crosses the miter line of the elbow C C', so that it can be located upon the stretchout line, where it is marked *a'*.

For the pattern of the pipe K L M N proceed as follows: At right angles to K L draw the line M' M², upon which lay off the stretchout of O P R S, as shown by the small figures, through the points in which, and at right angles to it, draw the

usual measuring lines, which intersect with lines of corresponding numbers drawn at right angles to the line of the pipe L K from the intersections on the miter line K Z N. A line traced through the intersections thus obtained, as shown by M' N' K' N² M², will be the required pattern for the intersecting pipe.

To avoid confusion of lines in developing the patterns of the intersected pieces of the elbows a duplicate of those parts, as shown by B C D D' C' B', is given in Fig. 350, in which the miter line K Z N is also shown. The profiles F G H J and O' P' R' S' are presented merely to show the relationship of parts, as the patterns are obtained from the miter line K Z N, in connection with the stretchout of as much of the profile as is covered by the intersection. It is not necessary to include in this operation the entire elbow pattern, therefore only such a part of the pattern will be developed as is contained in profile from V to H.

For the pattern for that portion of elbow shown in elevation by U Z N or V H of profile, proceed as follows: At right angles to C D of elevation draw the line R S, upon which lay off the stretchout of V H of the profile, as indicated by the small figures, through which draw the usual measuring lines at right angles to it, which intersect with lines of corresponding numbers drawn from the intersections on the miter line Z N at right angles to C D. Trace a line through the intersections thus obtained, as shown by U² Z² N'. Then will U² Z² represent the pattern for that part of elbow shown in elevation by U Z, and Z² N' be the pattern for the cut on the miter line Z N. The pattern for the other half of opening shown by N' X V² S is simply a duplicate of the half just obtained reversed. Then X N' Z² shows the shape to be cut out of what would otherwise be a regular elbow pattern. The point *a* in the profiles O' S' and V H is so near the line drawn from the point 4 that separate lines are not shown, and on this account when obtaining the shape of K' Z' the points 4 and *a* are shown on the same line.

In order to show that the pattern is produced by the regular method—that is, by the intersection of points from the miter line into lines of corresponding number in the stretchout—it should be noted that the profile and stretchout of the piece already developed is properly designated by the figures 1, 2, 3, *a*, 5, 6, while that of the piece next to be considered is properly designated by the figures 1, 2, 3, 4*a*, 5, 6, the point 4 not occurring in the first piece at all, while the points 4 and *a* both fall upon the same line in the stretchout of the second piece, all of which is clearly shown.

The pattern of the cut on the miter line K Z is obtained in the same manner as for Z N. At right angles to B C draw the line R' S', upon which place the stretchout of V H of the profile, as shown.

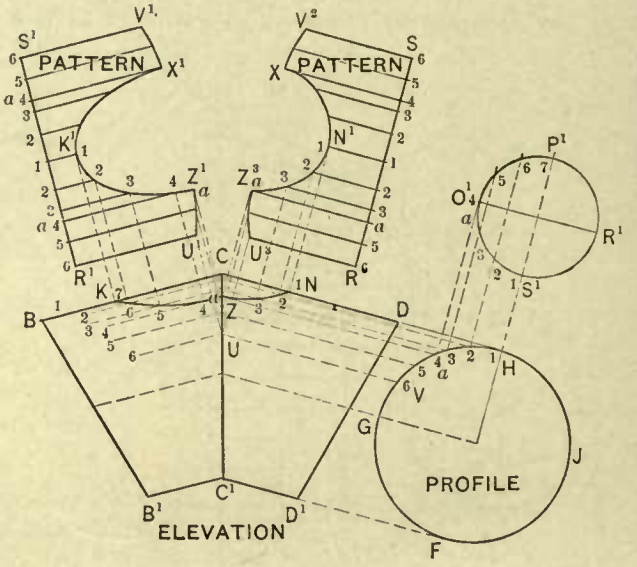


Fig. 350.—Patterns for the Pieces of an Elbow Intersected by the Pipe.

Through the points in the stretchout and at right angles to same draw the usual measuring lines, which intersect with lines of corresponding numbers drawn from the intersections on the miter line K Z, at right angles to B C. Trace a line through the intersections thus obtained, as shown by K' Z' U'. Then will Z' U' represent the pattern for that part of elbow shown in elevation by Z U, and Z' K' be the pattern for the cut on the miter line Z K. The pattern for the other half of opening shown by K' X' V' S' can be obtained by duplication. Then will X' K' Z' represent the shape to be cut out of the regular elbow pattern.

PROBLEM 62.

The Pattern for a Gable Molding Mitering Against a Molded Pilaster.

Let N X V E in Fig. 351 be the elevation of a gable molding of which A B C D is the profile, and K O M L be the elevation of a molded pilaster against which it is required to miter. The profile of the pilaster is shown by J I H in the plan, where a profile of the gable mold A' B' C' D' is also shown and so placed as to show the comparative projection of the various points in each. By an inspection of the plan and elevation it will be seen that the miter line or joint between the molding and the pilaster will not be straight from N to E, as would be the case if the side of the pilaster were perfectly flat and projected further than the gable molding. It will therefore be necessary to first obtain a correct elevation of the miter, after which the pattern can be obtained in the usual simple manner.

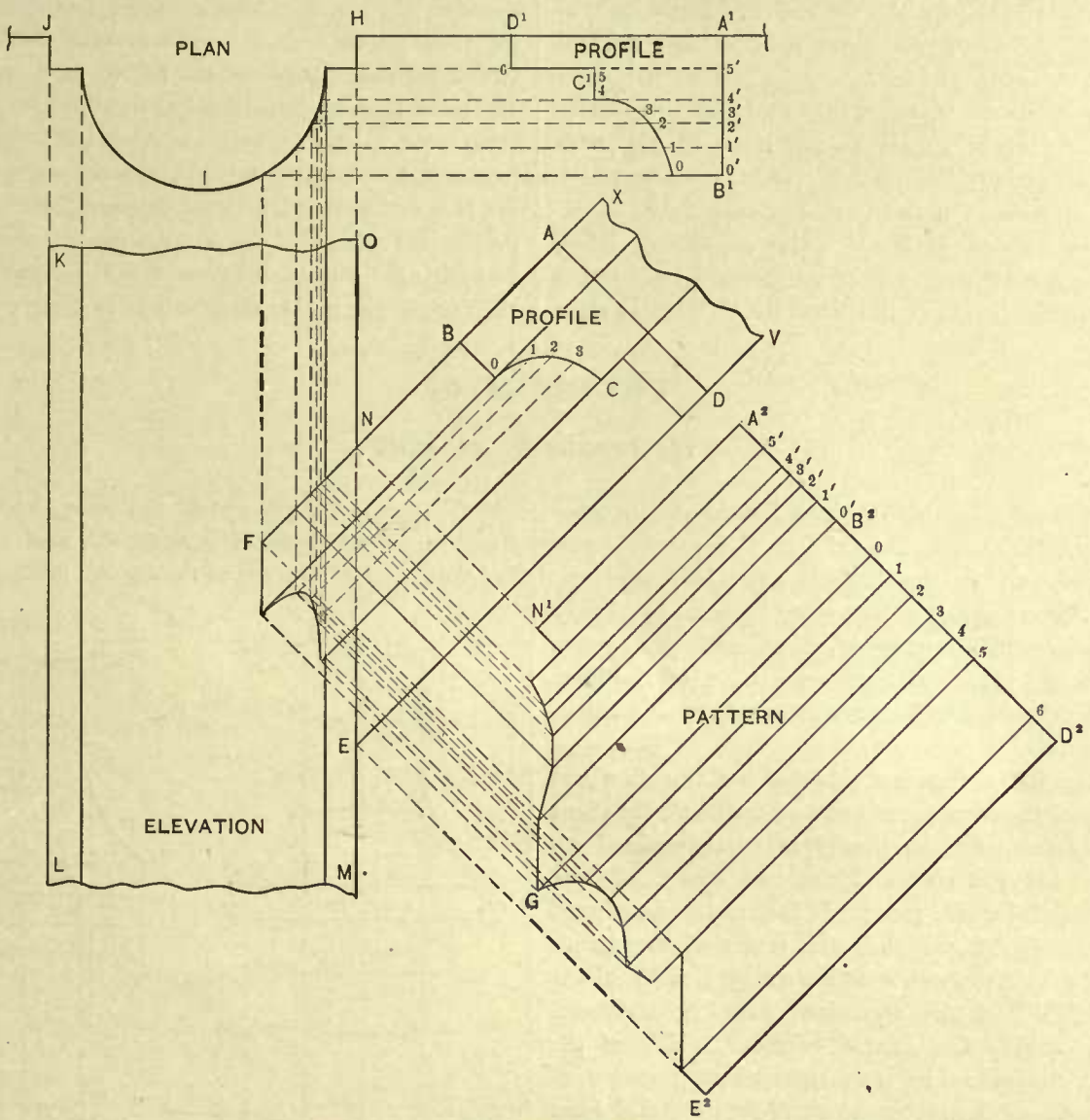


Fig. 351.—The Pattern for a Gable Molding Mitering Against a Molded Pilaster.

To do this divide the profiles in the plan and elevation into the same number of equal parts, commencing at the same points in each, as shown by the corresponding figures. From the divisions in the pro-

file in plan carry lines to the left, parallel to H A', until they cut the side of the pilaster H I J, as shown. From these intersections drop lines at right angles to H A' indefinitely, as shown. From the divisions in the profile in elevation draw lines parallel to N X until they intersect corresponding lines drawn from H I in plan. A line traced through these intersections, as shown by N F E, will be the required miter line, or intersection of the gable molding with the upright pilaster at the angle O N X.

For the pattern of the gable molding proceed as follows: At right angles to the lines of the gable molding draw the stretchout line A^2 D^2, upon which place the stretchout of the profile of the gable molding, through which draw the usual measuring lines, which intersect with lines of corresponding number drawn from the points in the miter line N F E at right angles to the lines of the gable molding. A line traced through these intersections, as shown by N G E^2, will be the required pattern.

Although the roof strip A B of the gable molding is perfectly straight, points will have to be introduced between A and B for the purpose of ascertaining the shape of the cut from N to F, its intersection with the side of pilaster. The simplest method of obtaining these points is to derive them from the points between B^1 and C^1, as shown by 0′ to 5′ in the plan. They can then be transferred to their proper place in the stretchout, as shown, between A^2 and B^2. By so doing points of like number fall in the same place on the profile H I, and the vertical lines dropped therefrom can be intersected with F N for the pattern of the roof strip and with the other lines from F to E for the pattern of the face of the mold, all of which is clearly shown.

PROBLEM 63.

The Patterns for an Anvil.

It frequently occurs that sheet metal reproductions of various emblems or tools are desired for use as ornaments or signs. In the following problem is shown how the various pieces necessary to form an anvil may be obtained. The description, of course, only applies to the several sides, as a representation of the horn can only be obtained by hammering or otherwise stretching the metal.

In Fig. 352 is shown a side and end elevation and two plans of the anvil, exclusive of the horn, the plans being duplicates and so placed as to correspond respectively with the side and the end views. Before the pattern of the side piece J N B G can be developed the line O P Q R S, which is the result of the mitering together of the two forms shown by U V W of the plan and Z X T of the end view, must be obtained. Therefore divide the curved portion Z X T of the profile of the side into any convenient number of equal spaces, as shown by the small figures, and from the points thus obtained drop lines vertically cutting W^1 V^1 U^1, the profile of the gore piece. Transfer the points thus obtained on W^1 V^1 U^1 to W V U of the other plan, and from these points erect lines vertically through the elevation of the side, and finally intersect them with lines of corresponding number drawn from the points originally assumed in Z T. Then a line traced through the points of intersection, as shown by O P Q R S, will be the required miter line.

To obtain the pattern of the side, first lay off a stretchout of the profile Z T, as shown, upon *v q*, through the points in which draw the usual measuring lines.

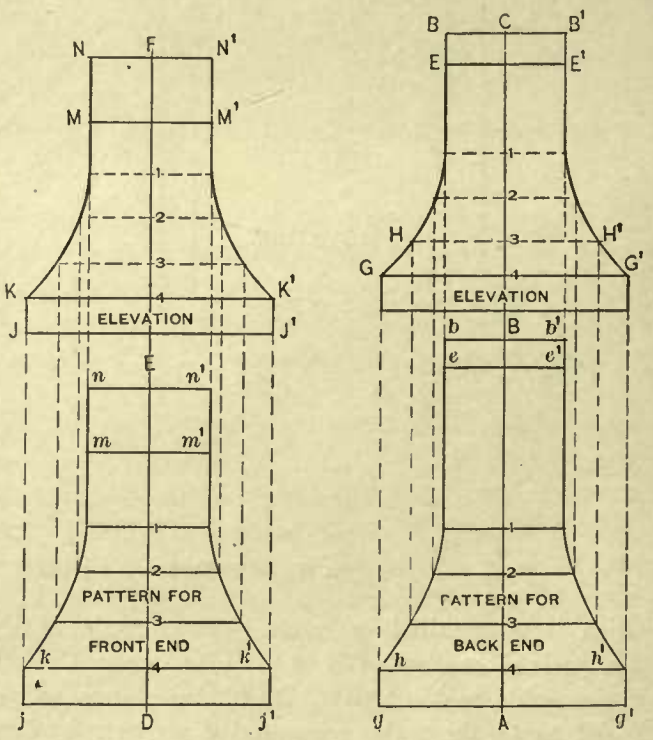


Fig. 353.—Patterns for the End Pieces of an Anvil.

With the T-square placed parallel with J G drop lines from the points in the profile Z T cutting the outlines

of the side from J to *a* and G to *b*, and also cutting the miter lines of the gore piece O Q S (which last operation has really been done in the raking operation above described). Placing the T-square parallel with *v q*, bring it successively against the points in the several miter lines of the side elevation and cut corresponding measuring lines; then lines traced through the points of intersection, as shown, from *j* to *c*, *o* to X, X to *s* and *g* to *d*, will give the pattern for the lower portion of the side. As that part of the side from Y to Z of the profile is straight and vertical, that portion of the pattern shown on the stretchout line from X to *q* can be made an exact duplicate of that part of the elevation shown by *a* M N B E *b*, all as shown.

For the pattern of the gore piece, U V W is the profile and O Q and Q S are the miter lines. By means of the points previously obtained upon the profile in the raking operation, lay off a stretchout of the same upon any line running at right angles to the form of this piece, as shown upon U^2 W^2. As the points have already been dropped from the profile to the miter lines in the operation of obtaining them, it only remains to place the T-square parallel to U^2 W^2 and bring it successively against the points in O Q and Q S, cutting corresponding measuring lines; then lines traced through the points of intersection, as shown by U^2 Q' and Q' W^2, will give the pattern for the gore piece.

For the end pieces of the anvil, N M *a* K J and B E *b* H G of the side elevation become the profiles, and Z T and Z' T' are the miter lines. Therefore, to obtain the pattern of either of these pieces, independently of the preceding operations, space the curved portion of its profile into any convenient number of

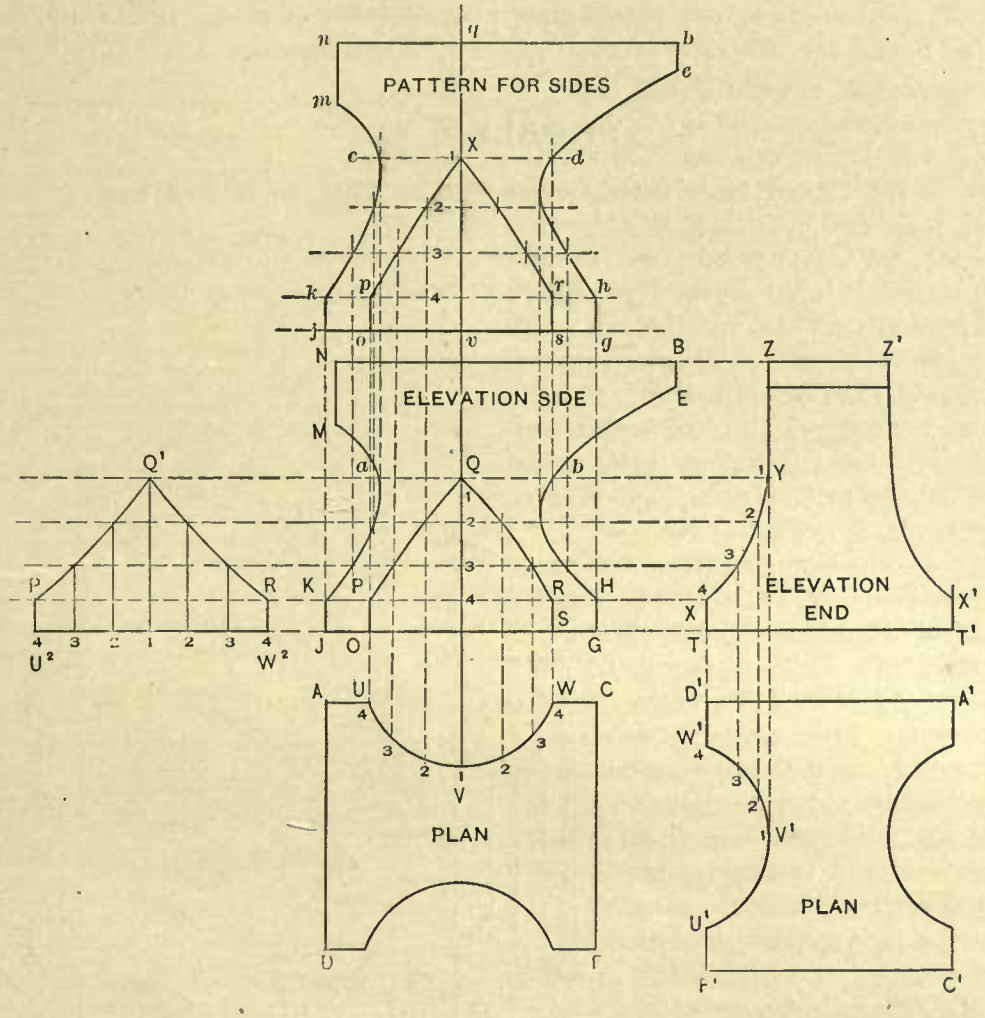


Fig. 352.—Patterns for the Side, Gore Piece and Bottom of an Anvil.

spaces, and lay off a stretchout of the same upon any line at right angles to T T'. Carry lines from the profiles parallel to N B, cutting the miter lines, thence at right angles to T T', cutting corresponding measuring lines. To avoid confusion of lines the operation of obtaining the patterns of the end pieces has been shown separately in Fig. 353, in which J N N' J' is an elevation of the front end and G B B' G' that of the back end. The points made use of, however, upon their profiles, in Fig. 352, are such as were obtained there in cutting the pattern of the side; therefore their stretchouts must be transferred point by point to the stretchout lines; E D of Fig. 353 being the stretchout of N *a* J in Fig. 352 and B A of Fig. 353 being that of B *b* G. In consequence of the above the points upon the miter line Z T are such as were originally obtained there by spacing, and have been transferred to the lines N J, N' J', B G and B' G'. The remainder of the work is shown sufficiently clear to need no further explanation.

PROBLEM 64.

The Pattern for a Gable Cornice Mitering Upon an Inclined Roof.

In Fig. 354 let A B C G represent one side of the gable molding and N O M its profile. H B F E represents the horizontal molding, and D C the upper line of roof. The profile of this molding is shown by K L, and the inclined roof by K J. Before the pattern for gable can be described it will be necessary to obtain an elevation of the intersection of the gable cornice with the inclined roof between C and B to be used as the miter line.

The first step to be taken in obtaining this miter line is to draw the profile of gable cornice, P Q R, directly over and in line with the profile of the horizontal molding J K L, as shown. Divide both profiles O M and P R into the same number of parts. From the points in O M draw lines parallel with the rake, extending them indefinitely in the direction of C B. From the points in P R drop lines upon the roof line J K, and from the points of intersection in J K carry lines horizontally across to the elevation, intersecting them with lines of corresponding number previously drawn from O M. Through the points of intersection trace a line, which will be at once the correct elevation of the miter and the miter line from which to obtain the pattern. If the pattern of gable at A G is required, in connection with that at the foot, extend the lines from points in M O to the miter line A G.

To obtain the pattern of A B C G, proceed as follows: At right angles to A B of gable lay out a stretchout of M O, as shown by S T, through the points in which draw the usual measuring lines. Place the T-square at right angles to the gable line A B, and, bringing it successively against the several points in A G and C B, cut corresponding measuring lines, all as indicated by the dotted lines.

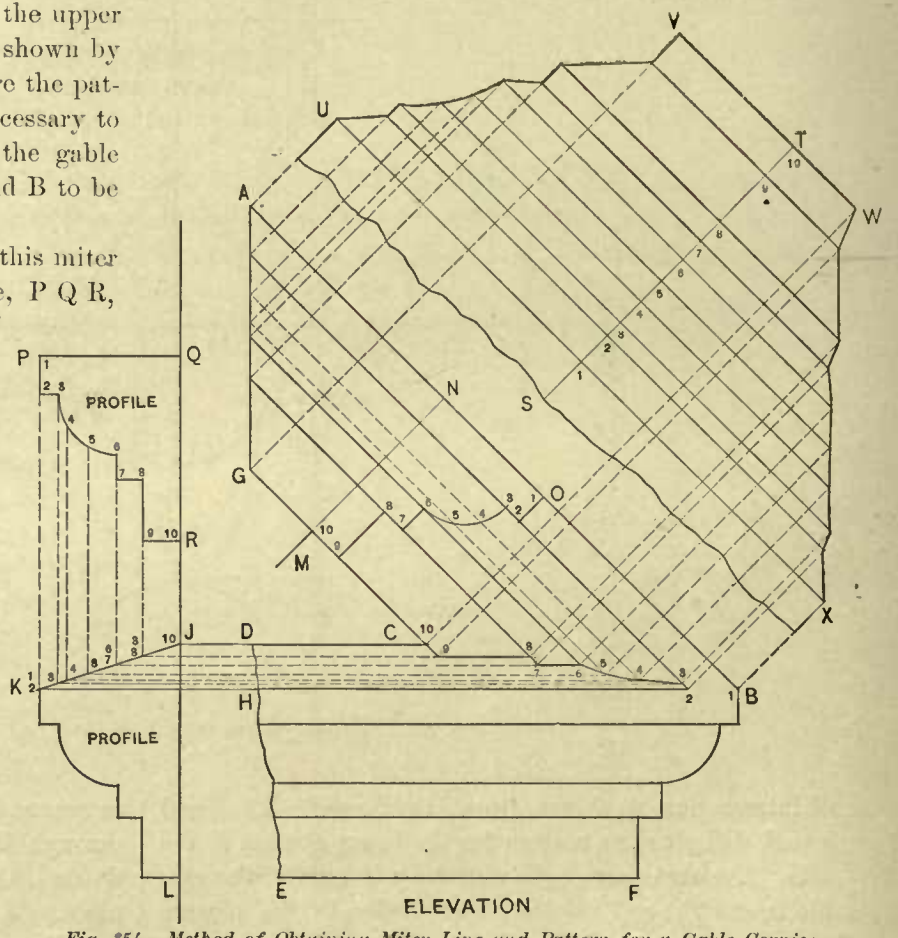


Fig. 354.—Method of Obtaining Miter Line and Pattern for a Gable Cornice Mitering Upon an Inclined Roof.

Thus the line U X of pattern is of the same length as A B of elevation, and V W of pattern the same length as G C of elevation, etc. It is evident that the various lines in pattern are of the same length as lines of corre-

sponding number in elevation. Through the points obtained in the pattern trace lines as indicated by U V and W X. Then U V W X is the pattern for the part of gable shown by A B C G in elevation.

PROBLEM 65.

The Pattern for the Molding on the Side of a Dormer Mitering Against the Octagonal Side of a Tower Roof.

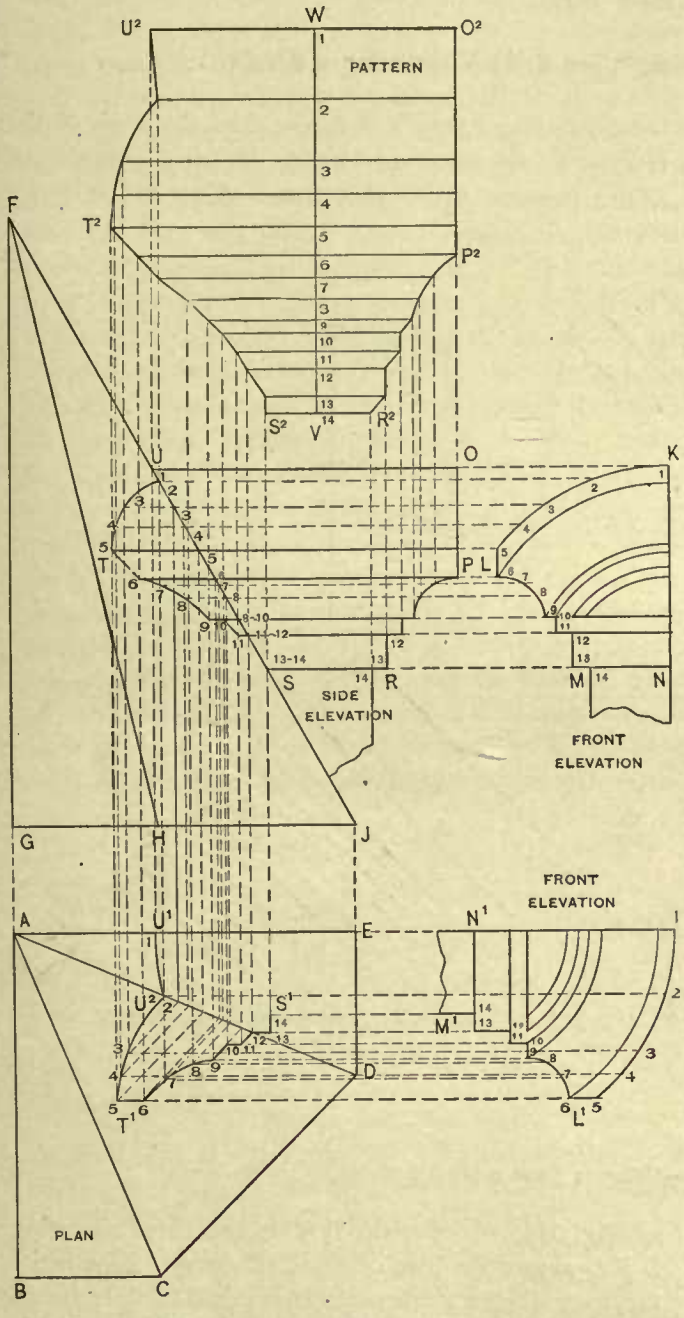


Fig. 355.—The Pattern for the Molding on the Side of a Dormer Mitering Against the Octagonal Side of a Tower Roof.

Let F J H G in Fig. 355 represent a half elevation of a portion of the tower roof corresponding to A B C D E of the plan; also let U O P R S be the side elevation of a dormer cornice for which the pattern is required, K L M N being half the front elevation of the dormer, and profile of the molding. The first step before the pattern can be described is to obtain a correct elevation of the miter line or intersection of the cornice with the oblique side of the tower, as shown by U T S. To obtain this miter line proceed as follows: On A E of the plan extended as a center line, as N' K', draw a duplicate of the half front elevation corresponding to the half E D of the plan as shown by K' L' M' N'. Now divide the two profiles of the return molding into the same number of parts, commencing at the same points in each, as shown by the small figures.

From each of the points in the upper front elevation carry lines parallel with U K cutting the side F J of the tower, and for convenience in obtaining the miter line extending them into the figure, as shown. From the intersections obtained on the side of the tower, as shown by the small figures in U S, drop lines parallel to the center line F G until they cut the miter line A D of the plan.

From the points in A D draw lines parallel with C D (the oblique side), extending them indefinitely toward A C. Now from the points in the lower front elevation K' L' M' draw lines parallel with A K', producing them until they meet or intersect lines of corresponding numbers, just described. A line traced through these intersections, as shown by U' U² T' S', will give the shape of the miter line as it will appear in plan, U² T' S' showing that portion of the intersection which occurs upon the oblique side of the tower roof.

From the points of intersection in the miter line U² T' S' of the plan erect lines parallel to A B, producing them until they intersect lines of corresponding numbers drawn from the profile K L M N through the side elevation.

A line traced through these intersections, as shown

in U T S of the elevation, will be the miter line in elevation, formed by the junction of the return with the oblique side of the tower A D C of the plan.

To obtain the pattern proceed as follows: At right angles to U O of the elevation draw the line V W, as shown, upon which lay off the stretchout of K L M of the front elevation, as shown by the small figures, through which draw the usual measuring lines, which intersect with lines of corresponding numbers drawn at right angles to U O of the elevation from the points of intersections in the miter line U T S and from the points of intersections in the profile O P R. A line traced through these intersections, as shown by U^2 T^2 S^2 R^2 P^2 O^2, will be the required pattern.

PROBLEM 66.

The Pattern for an Inclined Molding Mitering Upon a Wash Including a Return.

As a feature of design, it frequently occurs that a belt course between stories is carried around pilasters which occur between all the windows of a front, and between the pilasters and partly upon the wash of the returns at the sides of pilasters. Such a condition of affairs presents some interesting features and is shown

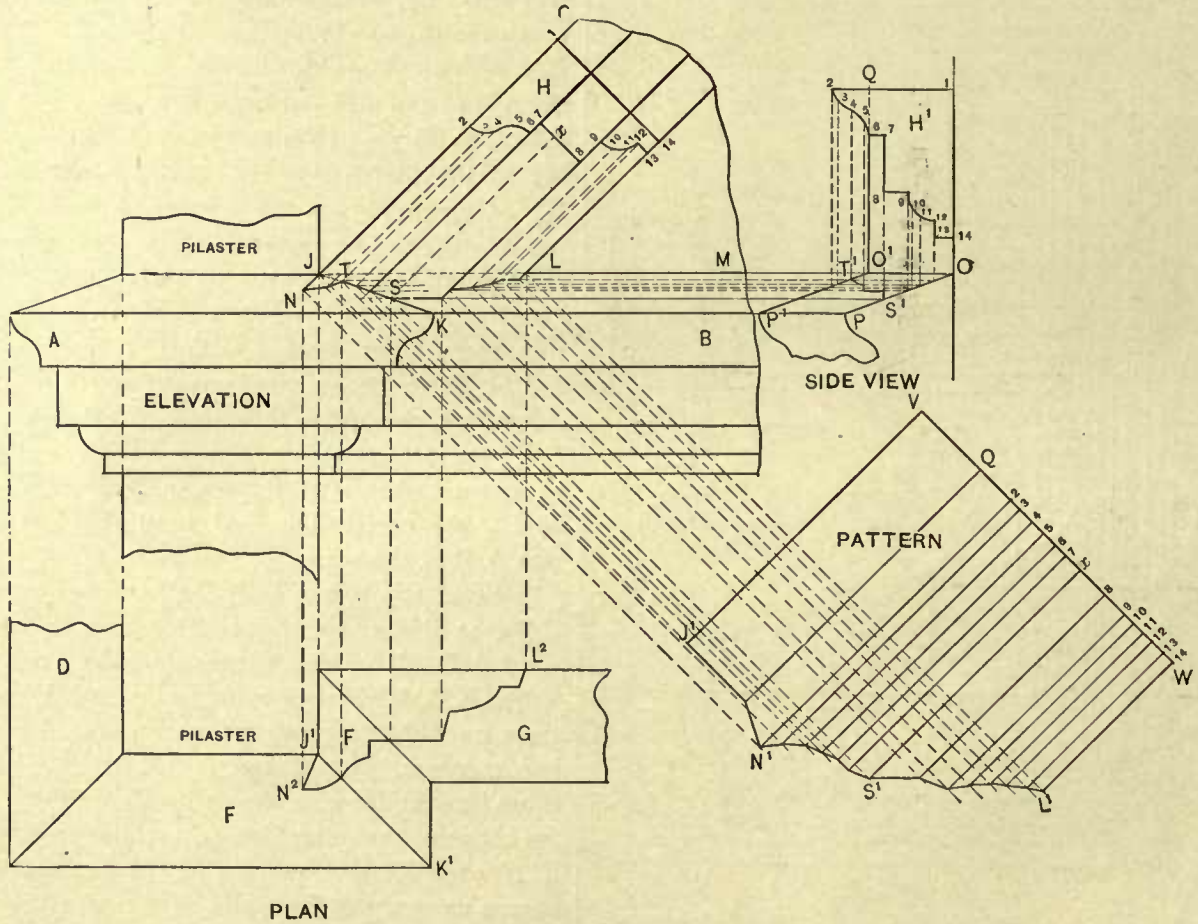


Fig. 356.—The Pattern for an Inclined Molding Mitering Upon a Wash Including a Return.

which rise from the foundations to the main cornice. In a certain instance, small gables or pediments were introduced between the pilasters in such a manner that the miters at the foot of the gables came partly upon the roof or wash of that part of the belt course lying in Fig. 356, of which A B C is the front elevation. D E G shows the plan of the belt course, upon which the foot of the gable mold is required to miter in the vicinity of F. The gable mold, of which J C is the elevation and H the profile, is required to meet the

level cornice at the angle C J M, its top line starting from the point J. In this instance, as in many others, the first requisite is that of obtaining a correct elevation of the miter between the gable mold and the three washes. To facilitate this operation it will be necessary to draw a side view which will show the comparative projection of the gable mold, the pilaster and the belt cornice from the face of the wall, as shown at the right. Divide both profiles of the gable mold into the same number of spaces, as shown by the small figures. From the points in the profile H of the elevation carry lines parallel to C J, extending them across the line J L indefinitely. From the points in H' drop lines cutting the profile of the wash of the belt course O P so far as they fall within its projection. From the points in O P carry lines horizontally across the elevation till they intersect lines of corresponding number previously drawn from the profile H. Inspection will show that only the lower portion of the profile will miter upon the main wash and that, therefore, the above operation can be begun with advantage at point 14 and continued until a line traced through the points of intersection crosses the line J K, which is really the profile of the wash of the return. This, as will be seen, occurs at S, which point can be carried back to profile H (shown at x), where it will be subsequently needed in obtaining the stretchout of the gable mold. Above the point x of the profile all points will fall against the wash of the return J K until the projection of the mold carries them across the forward miter of the return (J' K' in plan), after which they will fall upon the wash in front of the pilaster. This point of crossing can be found by reversing the operation above described, thus: From points upon J K above S carry lines horizontally across to side view, intersecting them with lines of corresponding number dropped from profile H' until a line traced through points of intersection, shown by S' T', crosses the line O' P', as shown at point T', which point happens to coincide with point 4 of profile. From point 4 of profile H' lines are dropped upon O' P', from which they are carried horizontally across as in the first part of the operation till they intersect with lines of corresponding number drawn from points in profile H, as shown from T to N. Then the line J N T S L will be a correct elevation of the required intersection and can be used as the miter line from which to obtain the final pattern of the gable mold. With this as a miter line and H as a profile the remaining operation is performed in the usual manner. Upon any line, as V W, drawn at right angles to J C lay off a stretchout of the profile of gable mold. In obtaining this stretchout the position of point x must be obtained from profile H, while from profile H' is obtained the position of point Q, which shows the point at which the roof piece of the gable mold passes beyond the side of the pilaster, shown best at J' in the plan. With the T-square placed parallel to V W, and brought successively against the points in J N T S L, cut measuring lines of corresponding number. A line traced through the points of intersection, as shown by J' N' S' L', will give the required pattern. The plan view of the intersection is shown at N^2 L^2, with some of the lines of projection used in obtaining it, merely to assist the student in seeing the relation of parts, but is not necessary in the actual work of obtaining the pattern.

PROBLEM 67.

The Pattern for a Level Molding Mitering Obliquely Against Another Level Molding of Different Profile.

In Fig. 357 is shown the plan and a portion of the side view of a bay window. In the side view is also shown the section of a lintel molding, shown indefinitely by C D E F of the plan, which it is required to miter against the oblique side of the large cove under the bay window indicated by B C F of the plan. In Fig. 358 is shown an enlarged plan of the particular portion in which the miter occurs, the angle B C D being the same as B C D of Fig. 357. In Fig. 358, A B F G represents the base of the window and G E D C the lintel cornice. The profiles are shown respectively at Y and X. The lintel molding is continued in the direction of F G until it intersects the base of the window between G and C.

In order to obtain the pattern of that part of the lintel molding which abuts against the base of the

window indicated from G to C, it is first necessary to obtain the plan of the intersection or shape of the miter line, as shown in plan by G H C F. To obtain this miter line proceed as follows: Opposite to and in line with the profile Y draw a duplicate of X, as shown at Z. In placing the profile Z in position it must be remembered that as hights are all to be compared the vertical lines of each profile must be placed parallel

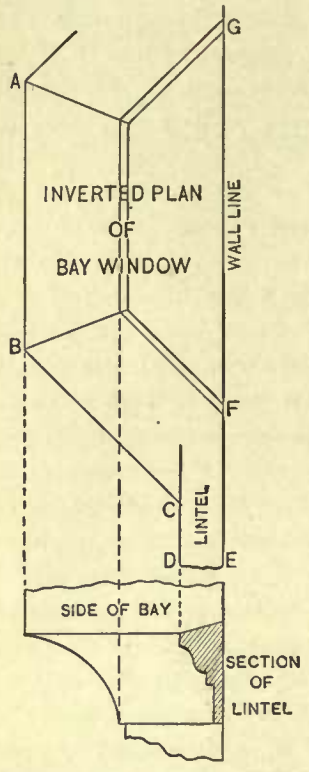


Fig. 357.—Plan and Sectional View of a Level Molding Mitering Obliquely Against Another Level Molding of Different Profile.

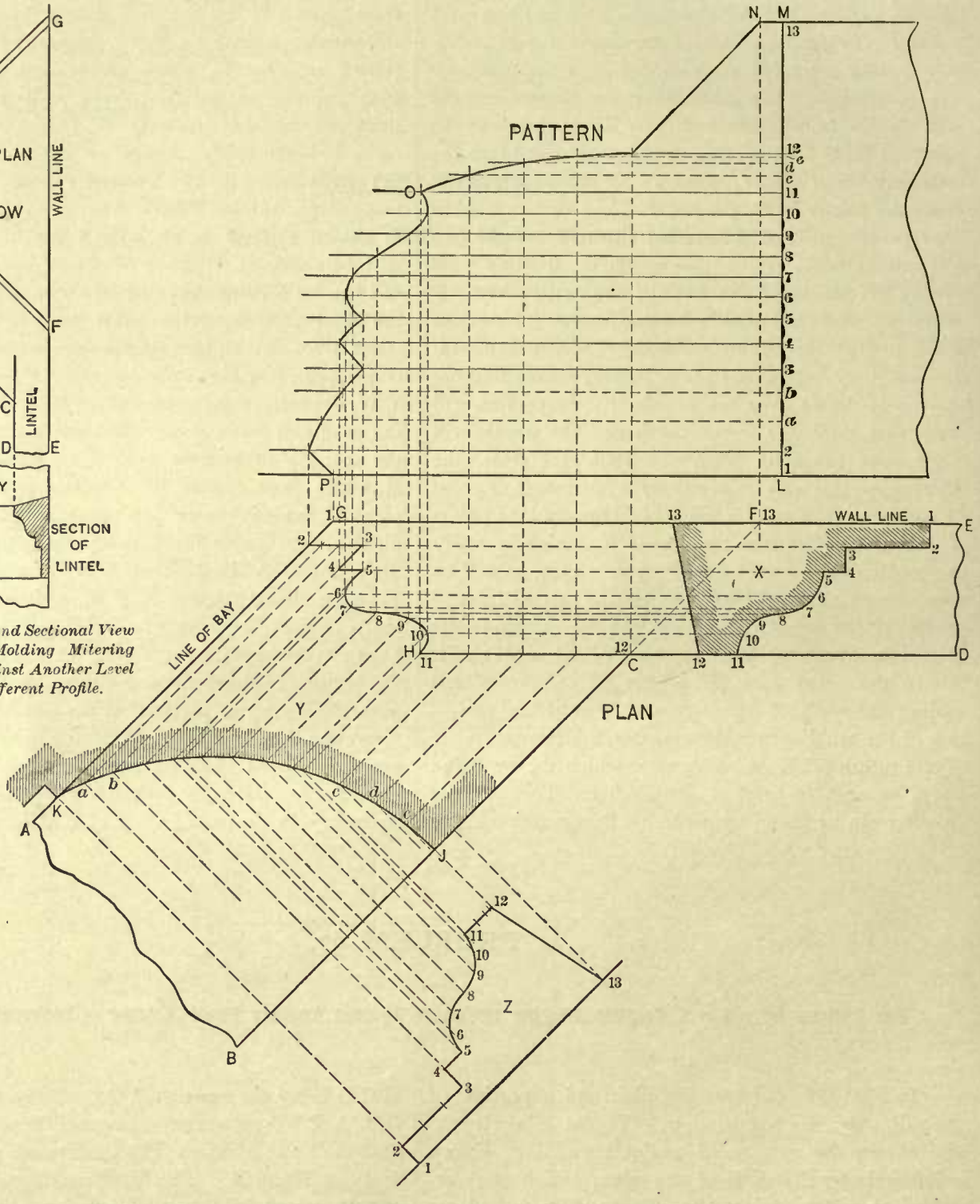


Fig. 358.—Method of Obtaining the Pattern of the Lintel Molding Shown in Fig. 357.

and their upper ends turned in the same direction. Therefore, the back or line 1 13 of the profile Z is placed parallel to B C, which represents a vertical line with reference to the profile Y, and the point 12 is placed exactly opposite the point J, according to the requirements of the side view, Fig. 357. Divide the profiles X and Z into the same number of parts, as indicated by the small figures in each. From the points thus obtained in profile Z carry lines at right angles to B C, cutting K J of profile Y, as shown. With the T-square placed parallel with the line B C of the plan of the window carry lines from the points on the profile K J in the direction of G and F; also draw lines from the points in the profile X parallel to G E, cutting the lines of corresponding number drawn from the profile Y. A line traced through points of intersection, as shown by G H C F, will give the miter line, as shown in the plan.

While the curved portions of the profiles X and Z have been divided into such a number of spaces as will answer the purpose of an ordinary miter, it will be noticed that the plane surfaces between points 2 and 3 and 11 and 12 intercept so much of the curve of K J as to produce a curve between those points in the pattern. Therefore, for accuracy it is necessary to subdivide those spaces on K J, as indicated by *a b* and *c d c* there shown. These points must be dropped back to the profile Z, and the spaces thus produced transferred to the stretchout line L M, all as indicated. The lines indicated by the small letters in K J have only been drawn part way in the engraving to avoid confusion, and the measuring lines produced by these points in the stretchout have been shown dotted for the sake of distinction. These points are then intersected with the surfaces to which they belong in the miter line G H C, as shown between 2 and 3 and 11 and 12.

For the pattern of the lintel molding first draw a line at right angles to it, as shown by L M, on which line lay off a stretchout of the profile X, as indicated by the small figures. Through the points thus obtained draw the usual measuring lines. With the T-square placed parallel with the stretchout line L M carry lines from the points in G H C F to measuring lines of corresponding number, when a line drawn through the points of intersection, as shown by N O P, will complete the pattern.

PROBLEM 68.

The Patterns for a Square Shaft of Curved Profile Mitering Over the Peak of a Gable Coping Having a Double Wash.

Let A B C in Fig 359 be the front elevation and D E F G H be the side elevation of a coping to surmount a gable, the profile of the top of which is shown at D K H in the side elevation. Also let M N O P be the elevation of a square shaft or base, as of a finial, having a curved profile, as shown, which it is required to miter down upon the top of the coping. As the matter of drawing the elevations of the shaft in correct position upon the washes of the coping is attended with some difficulty, the method of obtaining these will be briefly described first: Through the lowermost point on either side of the front elevation, as P, draw a line at the correct angle of the pitch of the coping or gable, as shown by V W, and extend the same to the right far enough to permit a section of the coping to be constructed upon it. Upon this line set off the distance X W, equal to P L (half the width of the shaft at its base), and through the point W draw a line perpendicular to V W; next through the point X draw a line, making the same angle with V W that D K, of the given profile of the coping, does with the horizontal line D L', and extend this line to the right till it meets the line from W at K', and to the left, making D' K' equal to D K. This gives one-half the profile of the wash, which is all that is necessary in obtaining the elevation. Now from the points in the profile D' K' project lines parallel to V W till they meet the center line of the front elevation, and duplicate them on the other side of the center line, which will complete the front elevation of the gable. From the points in the profile D K H erect vertical lines indefinitely, which may be intersected with lines projected horizontally from the points on center line I L to complete the side elevation. Thus a line from point B intersected with

line from K will give the apex of coping, and a line from point Z intersected with lines from D and H will give the points E and G, front and back of the washes at the apex.

As the shaft is exactly square, the side elevation of it, M' N' O' P', is in all respects the same as that of the front, and is drawn in line with it, as shown by the horizontal lines of projection connecting them. This having been completed, the point at which its side M' N' crosses the line E F (marked 4½) is projected back to the front elevation, as shown, thus locating the point U; while the crossing of the side O P with the top line of coping B C (marked 4) is projected upon the center line of the side view, thus giving the point Y. This completes the elevations with the exception of the lines M U P and M' Y P'. If the profile of the shaft O P were a straight line, either slanting or vertical, the lines U P and M' Y would be straight lines, because they would represent the intersection of two plain surfaces; but as the profile is a curved line it will be necessary to obtain correct elevations of these two lines, as they are essential in obtaining the patterns to follow.

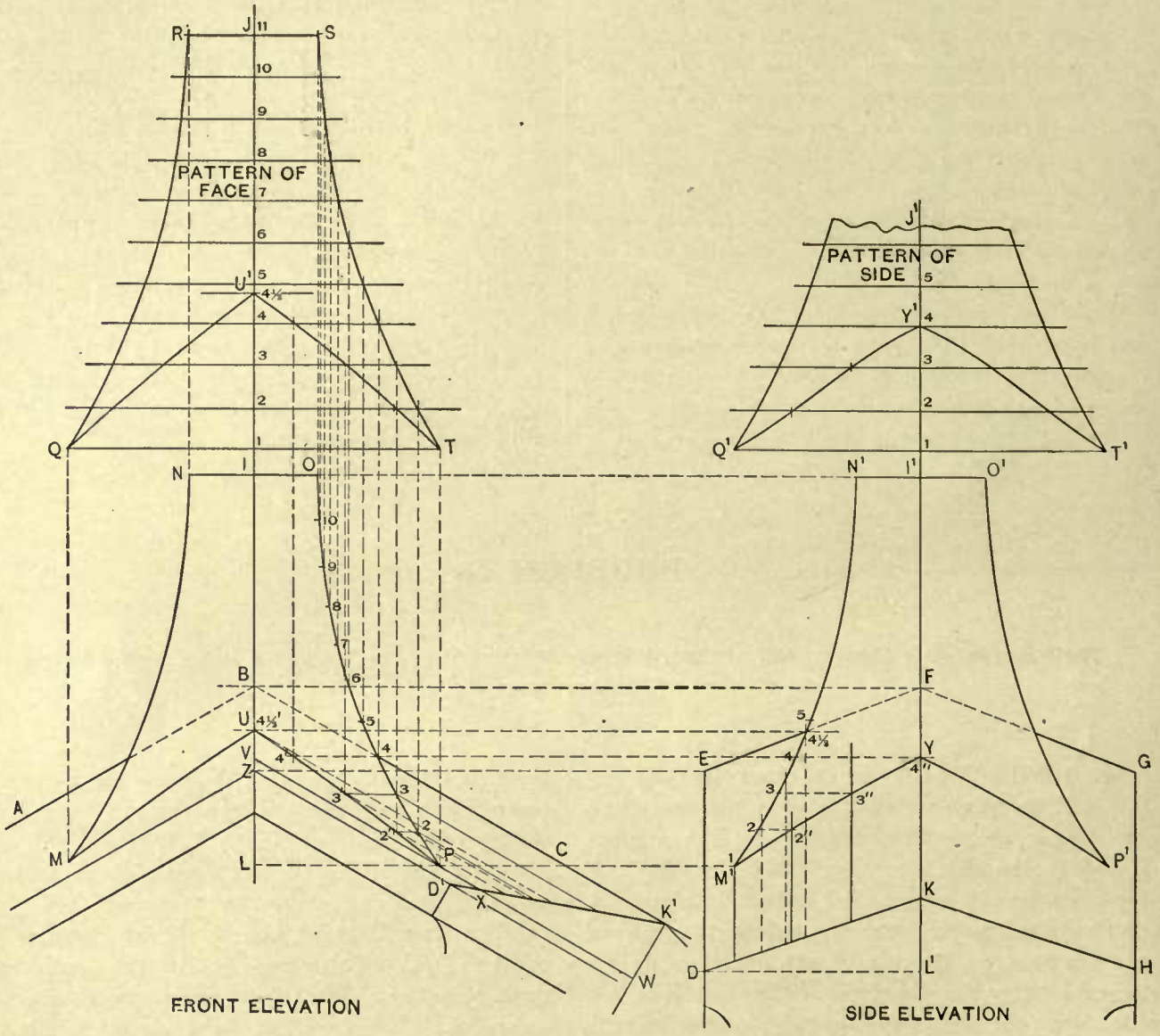


Fig. 359.—The Patterns for a Square Shaft of Curved Profile Mitering Over the Peak of a Gable.

The shaft being square, the miters at its angles are plain square miters and are developed by the ordinary method, as explained in several problems in the earlier part of this chapter. The peculiarity of this problem, then, consists in obtaining the miter lines U P and M' Y and the part of the pattern corresponding to the same, which can all be done at one operation, as follows:

Divide the profiles O P and M' N' into the same number of equal parts, and place the stretchout of the same upon the center lines extended, as shown at I J and I' J,' through which draw the usual measuring lines for subsequent use. From the points in M' N' from 4½ down drop lines vertically upon the profile of coping D K, as shown by the dotted lines, and transfer the points thus obtained to the profile D' K', from which points draw lines parallel to V W, as shown by the dotted lines. Intersect these with lines of corresponding number (2, 3 and 4) drawn horizontally from either profile, as shown at 2', 3' and 4', thus obtaining the miter line U P. After the points 1 to 11 of the profile have been dropped into the measuring lines of corresponding number of the stretchout the points 2', 3', 4' and 4½' are also dropped into the measuring lines of corresponding number, thus giving the cut U' T at the bottom of the pattern, which can be duplicated on the other side of the center line, thus completing the pattern Q R S T U' of the front of the shaft.

From the points 1 to 4 of the profile O P draw lines parallel to B C cutting the profile D' K', as shown by the solid lines, and transfer the same to the profile of coping D K, and from these points erect perpendicular lines (also shown solid) indefinitely, as shown, which intersect with lines drawn horizontally from points of corresponding number in either profile, as shown at 2,″ 3″ and 4″. This will give the correct miter line M' Y. The miters at the sides of piece M' N' O' P' are of course the same as those of the front piece, therefore after they have been obtained the points 2″ and 3″ are dropped into measuring lines 2 and 3 of the stretchout I' J', which when duplicated on the other side of the center line complete the line Q' Y' T', which is the bottom cut of the side piece.

It has been remarked that in obtaining the intersections between U and P and M' and Y horizontal lines may be drawn from points in either profile. The reason for this is simply that the two profiles O P and N' M' are identical and have been divided into the same number of equal parts. If a case should occur in which the side and face should be dissimilar it must be borne in mind that N' M' is the profile of the face piece and its points must be used in obtaining the intersections between U and P, while O P is the profile of the side piece, and its points must be used in obtaining the intersections between M' and Y.

PROBLEM 69.

The Patterns of a Cylinder Mitering with the Peak of a Gable Coping Having a Double Wash.

Let A B C in Fig. 360 be the elevation of a coping to surmount a gable, the profile of which is D E F E' D', which, as will be seen, shows a double wash, E F and F E'. Let M O P N be the elevation of a pipe or shaft which is required to miter over this double wash at the peak of the gable. Before any patterns can be developed it will be necessary to first obtain a correct elevation of the miter line or intersection of the shaft with the coping. To accomplish this proceed as follows: In line with the pipe or shaft construct a profile of the same, as shown by G' L' K' H', which divide into any convenient number of equal parts, and from the points thus obtained drop lines vertically through the elevation. Draw a corresponding profile, as shown by H G L K, directly over the profile of the coping, all as shown, which divide into the same number of equal parts, beginning to number at a corresponding place in the profile, and from the points in it drop lines on to the profile of the coping, cutting the washes E F and F E', and thence carry the lines parallel to the lines of the coping, producing them until they intersect the lines dropped from the profile G' L' K' H'. Through the points of intersection thus obtained trace a line, as shown from O to P, then O B' P will be the miter line in elevation.

As both halves of the shaft are alike (dividing on the line H L in one profile, and on H' L' in the other), it is really only necessary to use one-half of the profile,

as to use both halves as in the diagram requires the additional work of carrying the points from E F E' to the center line B B' for one-half and then down the other side of the gable for the other side. For the pattern of the shaft proceed as follows: In line with the end M N of the shaft, and at right angles to it, lay off a stretchout of the profile G' H' K' L', as shown by R S, in the usual manner, through the points in which draw measuring lines. Commence numbering these measuring lines with the figure corresponding to the point at which the seam is desired to be, in this case 1. Place the T square at right angles to the shaft, and, bringing it against the points in the miter line O B' P cut the corresponding measuring lines. Then a line traced through these points of intersection, as shown by T U V W X, will be the miter required. In case it should be desired to miter the coping against the base of the shaft, the pattern for it may be obtained from the same lines in the following manner: At right angles to the lines of one side of the coping, as A B, lay off a stretchout of the wash of the coping E F E', all as shown by E^2 F' E^3. In this stretchout line set off points corresponding to the points in E F E', obtained by the lines previously dropped from the profile G H K L. Place the T-square at right angles to A B, and, bringing it against the points in the miter line O B', cut lines of corresponding numbers drawn through the stretchout E^2 E^3, all as indicated by the dotted lines. Then a line traced through these points of intersection, as shown by Z I Y, will be the pattern of the wash for the side of the gable A B required to miter against the base of the shaft.

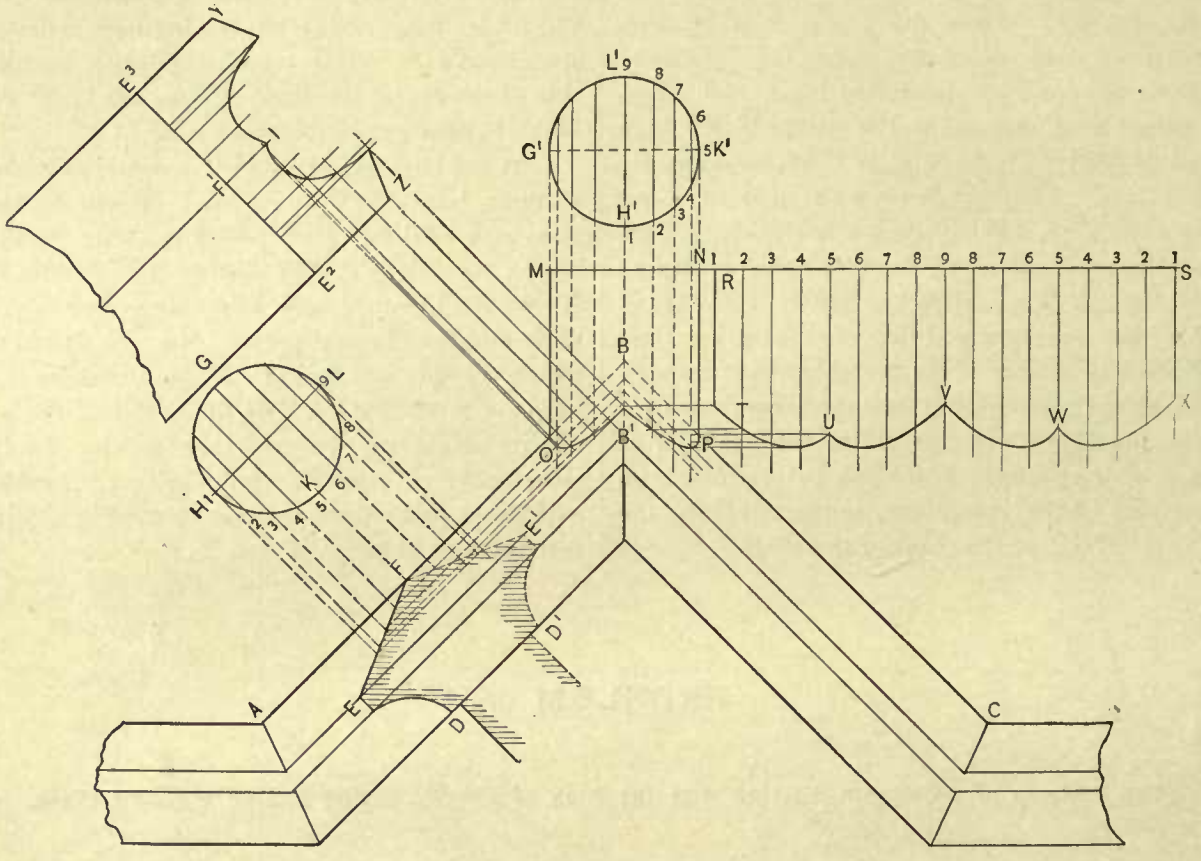


Fig 360.—The Patterns of a Cylinder Mitering with the Peak of a Gable Coping Having a Double Wash.

In case the design should call for a shaft octagonal in shape, the same general rules would apply. Less divisions, however, will be required in the profile, it only being necessary to drop points from each of the angles of the octagon, as in the case of Problem 33, previously given.

PROBLEM 70.

A Butt Miter of a Molding Inclined in Elevation Against a Plain Surface Oblique in Plan.

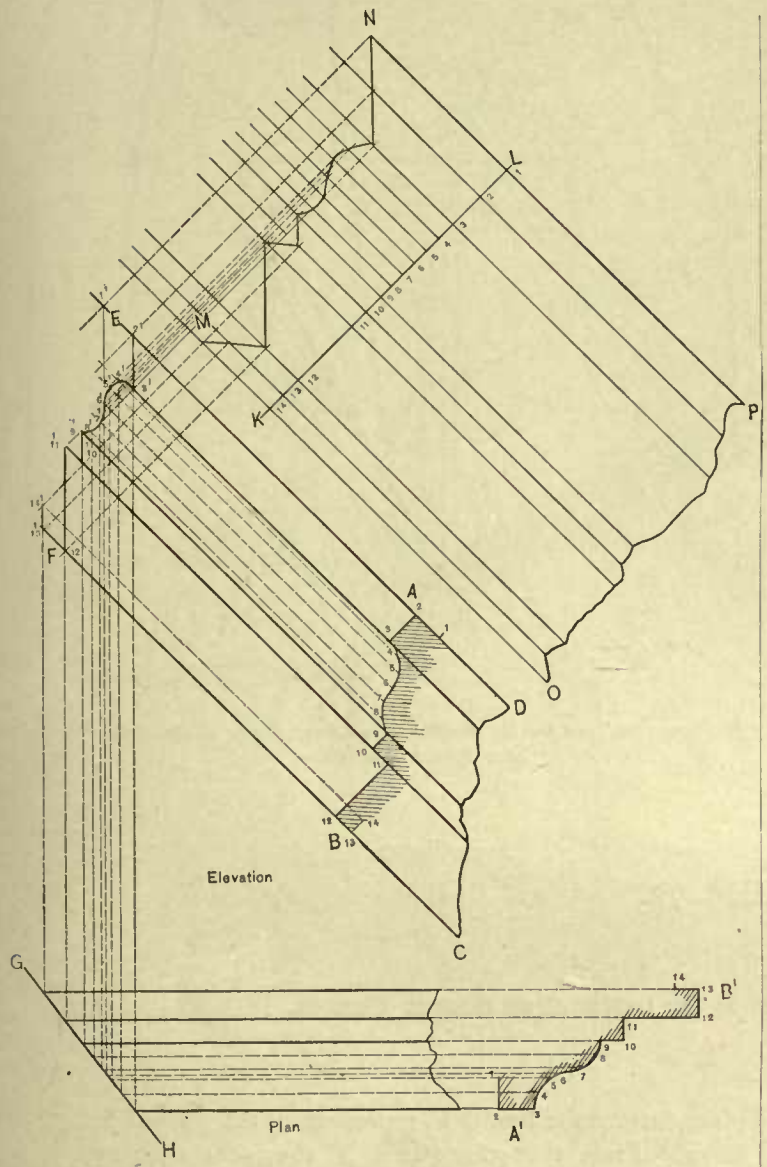


Fig. 361.—A Butt Miter of a Molding Inclined in Elevation Against a Plain Surface Oblique in Plan.

Let A B in Fig. 361 be the profile of a given cornice, and let E D represent the rake or incline of the cornice as seen in elevation. Let G H represent the angle of the intersecting surface in plan. The first step in developing the pattern will be to obtain the miter line in the elevation, as shown by E F. For this purpose draw the profile A B in connection with the raking cornice, which space in the usual manner, as indicated by the small figures. Draw a duplicate of this profile, as shown by A' B', placing it in proper position with reference to the lines of the plan. Space the profile A' B' into the same number of parts as A B, and through the points thus obtained carry lines parallel to the lines of the cornice, as seen in plan, cutting the line G H, as shown. In like manner draw lines through the points in A B, carrying them parallel to the lines of the raking cornice in the direction of E F indefinitely, as shown. Place the T-square at right angles to the lines of the cornice, as shown in plan, and, bringing it against the points of intersection in the line G H, carry lines vertically, cutting corresponding lines in the inclined cornice drawn from the profile A B. Through the points of intersection thus obtained trace a line, as shown from E to F. Then E F will be the miter line in elevation, formed by an inclined cornice of the profile A B meeting a surface in the angle shown by G H in the plan.

At right angles to the raking cornice lay off a stretchout of A B upon any line, as K L, and through the points draw the usual measuring lines, all as shown. Place the T-square at right angles to the lines of the raking cornice, and, bringing it against the several points in the miter line E F, cut corresponding measuring lines drawn through the stretchout K L. A line traced through these points of intersection, as shown from M to N, will be the pattern required.

PROBLEM 71.

Patterns for the Moldings and Roof Pieces in the Gables of a Square Pinnacle.

Fig. 362 shows the elevation of one of four similar gables occurring in a square pinnacle. The profile of the molding is shown at P. The first step is to obtain the miter line or elevation of the miter shown at K, from which to derive the pattern. Draw the profile P in the molding, as shown, placing it so that its members will correspond with the lines of the molding. Draw a second profile, P', in the side view

of the gable, placing it, as shown in the engraving, so that its members will coincide with the lines of the side view. Space both of these profiles into the same number of parts in the usual manner, and through the points thus obtained draw lines parallel to each of the moldings respectively, as shown, until they intersect, and trace a line through the points of intersection, as shown at K. Then K is the line in elevation upon which the moldings will miter. Draw the center line O M, which represents the miter at the top of the gable.

For the pattern of the molding lay off a stretchout of the profile upon any line, as G H, drawn at right angles to the line of the gable in elevation, as shown by the small figures. Through these points draw measuring lines, as shown. Place the T-square parallel to the stretchout line, or, what is the same, at right angles to the line of the gable, and, bringing it successively against the several points in the miter lines O M and K, cut the corresponding measuring lines, as shown, and trace lines through the intersections. This completes the pattern of the molding, to which the piece forming the roof may be added as follows: Make L D' equal to E D of the side view of the gable and set it off at right angles to L B'. In like manner, at right angles to the same line, set off A' B' equal to A B of the side view, and draw the lines D' A' and A' F, as shown.

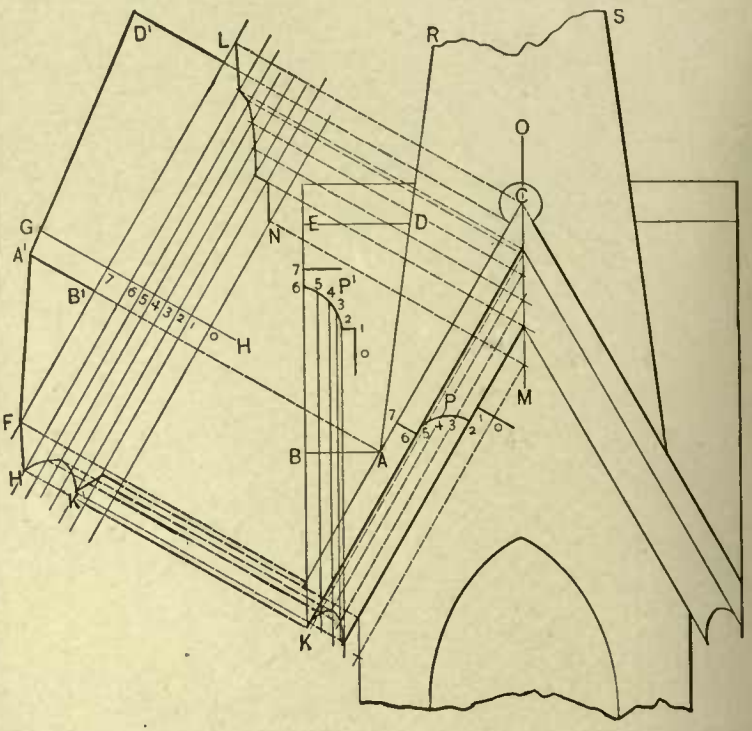


Fig. 362.—Patterns for the Moldings and Roof Pieces in the Gables of a Square Pinnacle.

PROBLEM 72.

Pattern for the Moldings and Roof Pieces in the Gables of an Octagon Pinnacle.

Fig. 363 shows a partial elevation and a portion of the plan of an octagon pinnacle having equal gables on all sides. The first step in developing the patterns is to obtain a miter line at the foot of the gable, as shown by L. To do this proceed as follows: Draw the profile K, as shown, placing it so that it shall correspond in all its parts with the lines of the molding in elevation. Divide into spaces and number in the usual manner, and through the points draw lines parallel to the lines of the gable toward L, as shown. Draw a duplicate profile in the plan, K', so placed as to correspond with the lines of the molding in plan. Divide it into the same number of spaces, and through the points in it draw lines parallel to the lines of the plan, cutting the line D F, representing the plan of the miter. From the points in D F thus obtained carry lines vertically, intersecting corresponding lines drawn from the profile in the elevation. A line traced through the several points of intersection, as shown by L, will be the line of miter in elevation between the moldings of the adjacent gables. The center line O N forms the miter line for the top of the gable.

For the pattern proceed as follows: Upon any line, as E E, drawn at right angles to the lines of the gable, lay off a stretchout of the profile, as shown by the small figures. Through the points of the stretchout draw the usual measuring lines. Place the T-square at right angles to the lines of the gable, and,

bringing the blade successively against the points in the two miter lines above described, cut the corresponding measuring lines, as shown. Lines traced through the points of intersection thus obtained will give the pattern of the molding. The roof piece may be added by setting off A' B' at right angles to A' C', equal in length to A B of the side view. In like manner, upon the line from M set off D' C' equal to C D of the side view. Then draw F' D' B', thus completing the pattern.

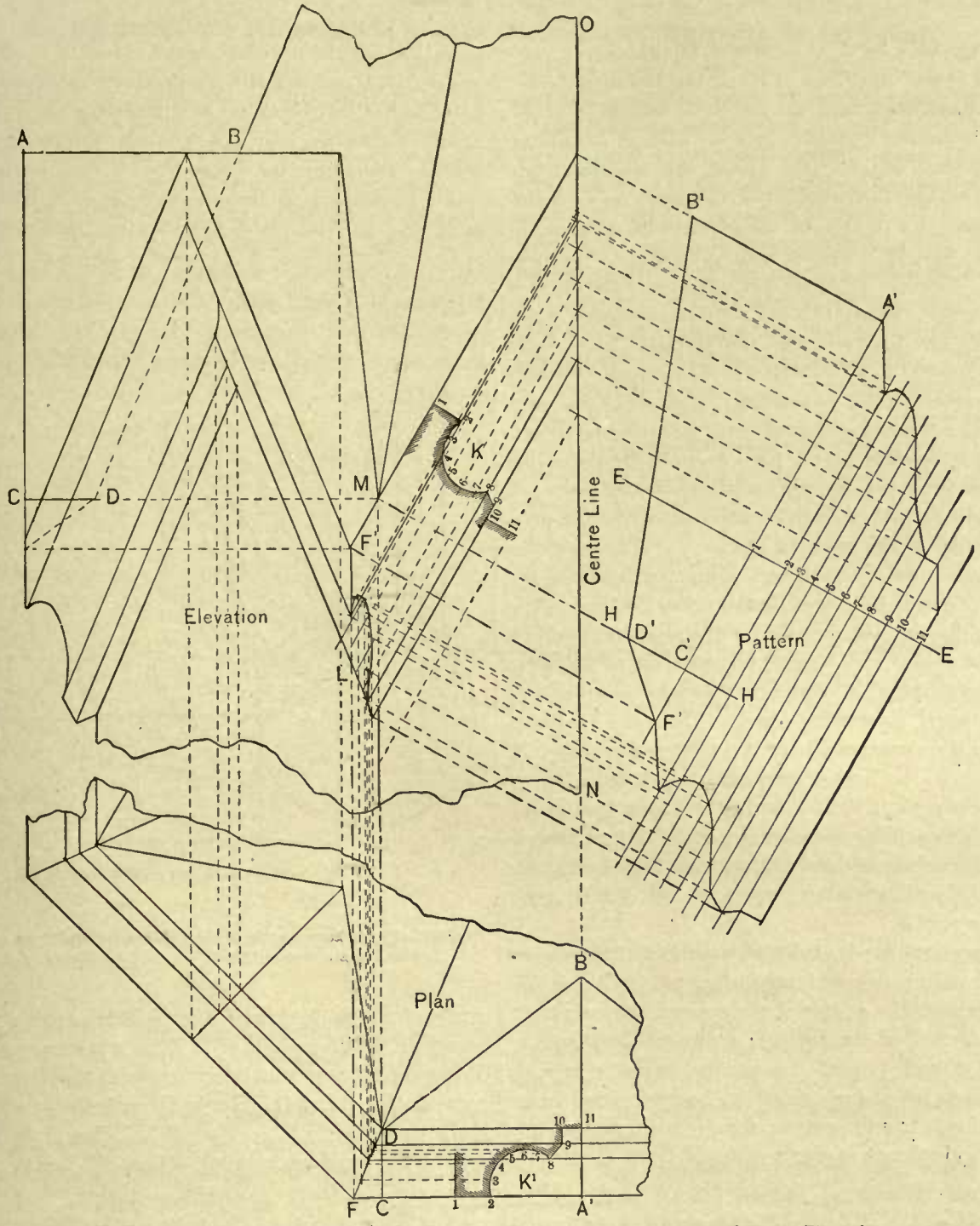


Fig. 868.—Pattern for the Moldings and Roof Pieces in the Gables of an Octagon Pinnacle.

PROBLEM 73.

The Pattern for the Miter Between the Moldings of Adjacent Gables Upon a Square Shaft, Formed by Means of a Ball.

In Fig. 364, let A C be one of the gables in profile and B D the other in elevation, the moldings forming a joint against a ball, the center of which is at E. The first operation necessary will be that of obtaining the miter line, or, in other words, the appearance in elevation of the intersection of the molding with the ball. Place the profile of the mold in each gable, as shown at F and H. Divide each of these profiles into the same number of equal parts, as indicated by the small figures. From the points thus obtained in F drop lines vertically, meeting the profile of the ball, as shown from C to J. From the center E of the ball erect a vertical line, as shown by E J. From the points in C J already obtained carry lines horizontally, cutting E J, as shown, and thence continue them, by arcs struck from E as center, until they meet lines of corresponding number dropped from points in the profile H parallel to the gable in elevation. Through the intersections thus obtained trace a line, as indicated by D G M. Then D G M will be the miter line in elevation. To develop the pattern for the molding, first lay off at right angles to the gable a stretchout of the profile, as shown by P R, through the points in which draw the usual measuring lines. Place the T-square parallel to the stretchout line, or, what is the same, at right angles to the lines of the gable, and, bringing it successively against the points in the miter line D M, cut the corresponding measuring lines. A line traced through the points of intersection from 2 to 7 (that is, from U to V) will give the pattern for the curved portion of the profile.

As any section of a sphere is a perfect circle whose length of radius depends upon the proximity of the cutting plane to the center of the sphere, the curves S to U and V to T of the pattern, representing the plain surfaces 1 2 and 7 8 of the profile, must be arcs of circles, whose lengths of radius can be determined from the elevation. As the pattern for the plain surface 1 2 is simply a duplicate of the cut from D to G of the elevation, set the dividers to the radius E G of the elevation, and from S and U respectively as centers strike arcs, which will be found to intersect at N. Then N is the center by which to describe the arc S U. To find the radius for the curve from V to T continue the line S M through the sphere, cutting its opposite sides at M and L; then M L will be the diameter of the

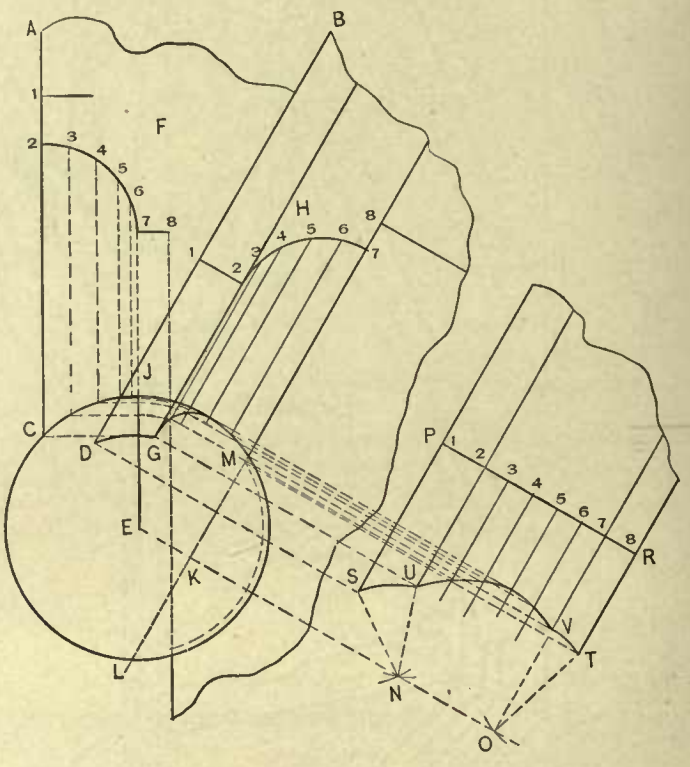


Fig. 364.—The Pattern for the Miter Between the Moldings of Adjacent Gables Upon a Square Shaft, Formed by Means of a Ball.

circle of which the arc 7 8 or V T is a part. Therefore with K M (one-half of M L) as a radius, and V and T respectively as centers, strike arcs, which will intersect in the point O. From O, with the same radius, describe the arc V T. Then S U V T will be the pattern of the molding to miter against the ball.

Note.—The remaining problems in this section of the chapter involve the necessity of "raking" or developing a new profile from the given or normal profile before the pattern for the required part can be obtained. One of the principal characteristics of this work is that, as the normal profiles are usually spaced into equal parts for convenience in beginning the work, the resulting or raked profiles must by force of circumstances be made up of a number of unequal spaces; in consequence of which their stretchouts must be transferred to given straight lines, space by space, as they occur upon the new profiles.

PROBLEM 74.

The Pattern of a Flaring Article of which the Base is an Oblong and the Top Square.

Let A B D E of Fig. 365 be the elevation of the article, and F N O I the plan at the base, K M P L being the plan at the top. If the sides are to be developed in connection with the top (supposing the bottom to be open) proceed for the pattern as follows: Draw K' M' P' L', Fig. 366, equal in all respects to K M P L of the plan. Through the center of it, and at right angles to each other, draw lines V U and S T indefinitely. While the elevation in Fig. 365 shows the slant hight of the ends it does not give the slant hight or profile of the sides, therefore through the elevation, and perpendicular to the base and top, draw the line C G, which will measure the straight hight of the article. From G set off G H, in length equal to M R of the plan. Draw H C. Then H C will be the profile of the article through the side, and therefore the width of the pattern of that portion. Upon V U of the pattern, from K' M', set off W V, and from L' P' set off X U, in length equal to H C of the elevation. Through U and V draw lines parallel to K' M' and L' P', making them in length equal to F N and I O of the plan, letting the points V and U come midway of their lengths respectively. Draw K' F', M' N', L' I' and P' O', thus completing the pattern for the sides. Upon S T set off Z T from M' P', and Y S from K' L', in length equal to A B or D E of the elevation, and through the points S and T draw F² I² and N² O² parallel to K' L' and M' P', and in length equal to F I and N O of the plan, letting the points S and T fall midway of their lengths respectively. Draw F² K' I² L', N² M' and O² P', which will complete the pattern of the ends.

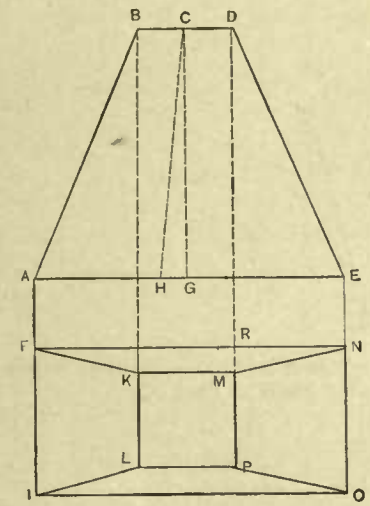


Fig. 365.—Elevation and Plan.

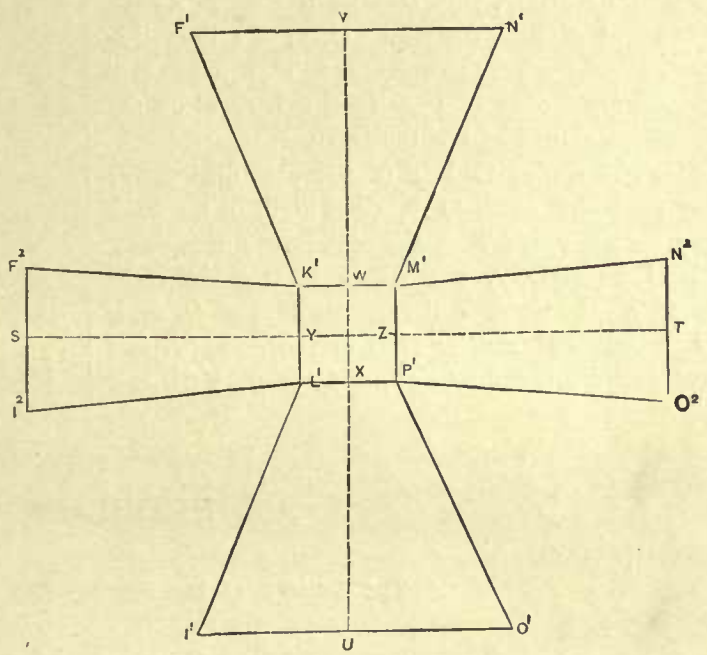


Fig. 366.—Pattern.

The Pattern of a Flaring Article of Which the Base is Oblong and the Top Square.

If it is required to produce the pattern with the sides joined to the bottom, supposing the top to be open, lay out first a duplicate of F N I O, through the center of which draw the stretchout lines V U and S T as before, and proceed in the same general manner as described above to obtain the sides, placing their wider ends against corresponding sides of the base or bottom.

PROBLEM 75.

The Envelope of the Frustum of a Pyramid which is Diamond Shape in Plan.

In Fig. 367, let A B D E be the elevation and K G I O the plan of the pyramid at the base. Project the points B and D into the plan, as shown, locating the points M and P, and draw the sides of the plan at top, each parallel to the corresponding line of the plan at the base. By projection from G or O of the plan draw C F of the elevation, representing O R of the plan and also the straight hight of the frustum.

Before the slant hight or stretchout of a side can be obtained it will be necessary to construct a section on any line crossing the plan of the side at right angles as S T. Therefore extend the top and bottom lines of the elevation, as shown dotted at the right, cutting the vertical line S^1 S^2, thus making S^1 S^2 equal to the straight hight of the frustum. Upon the base line extended set of from S^1 the distance S^1 T^1, equal to S T of the plan, and draw S^2 T^1. Then will S^2 T^1 be the true profile or slant hight of the frustum.

At right angles to M R of the plan draw S W, making its length equal to the slant hight of the frustum, as shown by S^2 T^1 of the section. Through W draw N H indefinitely, parallel to K O. At right angles to K O, through the points K and O, draw lines K N and O H, cutting N H in the points N and H, thus establishing its length. Connect M N and R H. Then M R H N will be the pattern of one of the four sides composing the article.

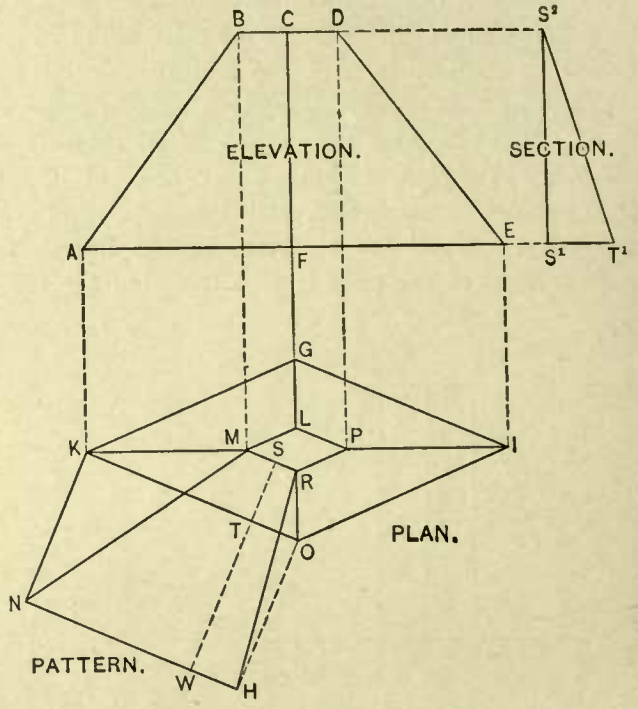


Fig. 367.—The Envelope of the Frustum of a Pyramid Which is Diamond Shape in Plan.

PROBLEM 76.

The Pattern of the Flaring End of an Oblong Tub.

In Fig. 368, A B D C shows the elevation and N P O R the plan of a vessel having straight sides and semicircular ends, one end of which is slanting. First draw a correct plan and elevation of the article, seeing that each point of the elevation is carefully projected from its corresponding point in the plan. Divide half of the boundary line of the top into any number of equal spaces, commencing at O, all as shown by the small figures 1, 2, 3, etc., in the plan. From the points thus obtained carry lines vertically until they cut the top of the elevation, as shown in the points between B and L; also continue the lines downward until they meet the line T O, all as shown. From the points between L and B thus obtained draw lines parallel to B D, producing them upward indefinitely, and continue them downward until they meet the bottom line of the elevation F D, as shown. At right angles to the lines thus drawn, and at any convenient distance from the elevation, draw G H. With the dividers, set off from the line G H, on each of the lines drawn through it, the distance from T O, on the lines of corresponding number, to the curved line P O. In other words, make G K equal to T 6 of the plan. Set off spaces on the other lines corresponding to the distance on like lines in the plan. Through the points thus obtained trace a line, as shown by K H. Then G H K will be the half profile of the end of the vessel on any line, as L M, drawn at right angles to

the line D B. The stretchout of the pattern is to be taken from the profile thus constructed. At right angles to D H, and at any convenient distance from it, draw U V, upon which lay off twice the stretchout of K H, numbering each way from the central point 1, as shown. From the points in the stretchout thus obtained draw measuring lines at right angles to it indefinitely. With the blade of the T-square set at right angles with D B, and brought successively against the points in F D, cut lines of corresponding number drawn through the stretchout. Then a line traced through the points of intersection, as shown by Y Z, will be the pattern of the bottom end of the piece. In like manner bring the blade of the T-square against the points in L B and cut corresponding measuring lines, as shown, for the top of the pattern. If it is desired to make a joint upon the line E F of the elevation, the triangular shaped piece E L F may be added to the pattern as follows: With the dividers take the distance E F of the elevation as radius, and from the point Z of the pattern as center describe an arc. In like manner, with E L of the elevation as radius, and point R in the upper line of the pattern as center, describe a second arc, cutting the first arc in the point W. Connect W with R and also with Z. The triangular piece at the opposite end terminating in point X is added in a similar manner, thus completing the entire pattern of that portion of the vessel from the line E F to the right.

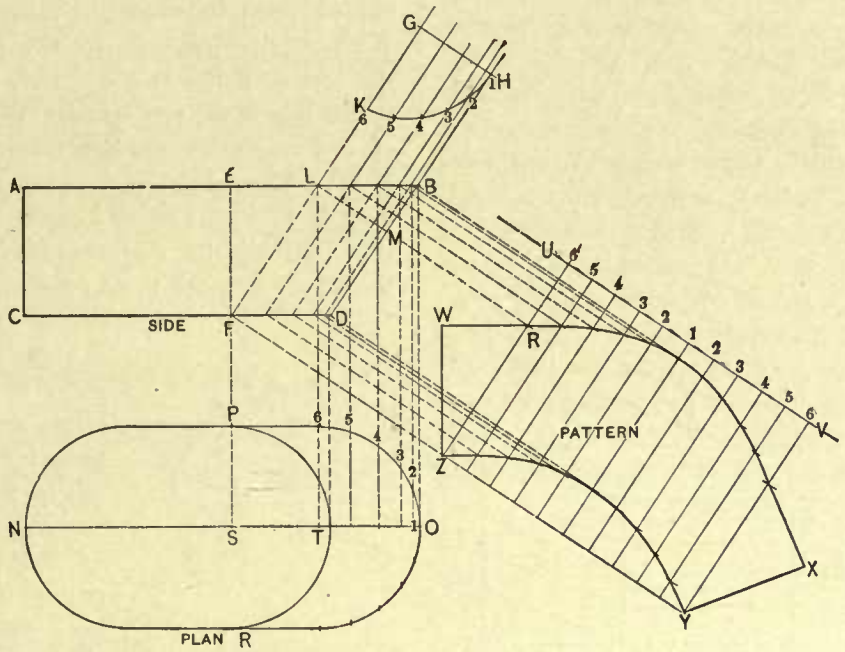


Fig. 368.—Pattern of the Flaring End of an Oblong Tub.

PROBLEM 77.

Pattern for the Flaring Section of a Locomotive Boiler.

While the pattern here described is especially adapted to the tapering section or "taper course" of a locomotive boiler its principles are equally applicable to tanks, cans or pipes whose shapes are governed by the spaces or positions which they are to occupy. The section of the boiler at A F, Fig. 369, is round, as shown by I N L M. The lower half of the circle I M L is the profile from L F to G D, but the upper half is raked or slanted from B K to C H, retaining its semi-circular character at C H. The line H G is a vertical

line, as shown by S L of the sectional view, and the surface H K G being vertical is simply a flat triangular surface, exactly as shown in the elevation.

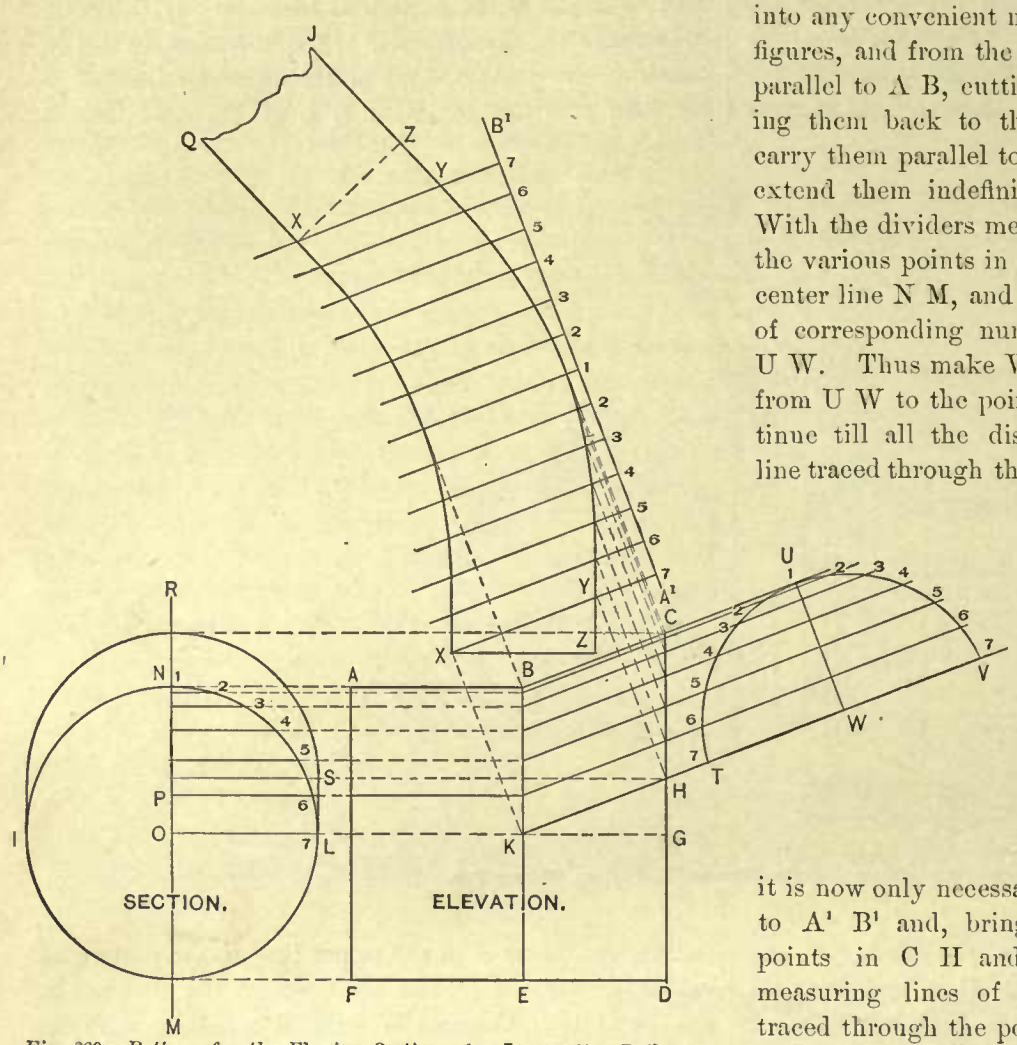


Fig. 369.—Pattern for the Flaring Section of a Locomotive Boiler.

Since the part B K H C is semicircular when cut upon any vertical line, the first step will be to obtain a section of it as it would appear if cut upon a line at right angles to B C. This section must be derived from the normal section of the level part, and may be done as follows: Assume any line, as U W, drawn at right angles to B C at any convenient position outside of the elevation, as the vertical center line of the new section. Divide one-half the normal section, as N L, into any convenient number of spaces, as shown by the figures, and from the points thus obtained draw lines parallel to A B, cutting B K, as shown, also extending them back to the center line N M. From B K carry them parallel to B C, cutting the line C H, and extend them indefinitely, cutting also the line U W. With the dividers measure the horizontal distance of the various points in the normal profile N L from the center line N M, and transfer these distances to lines of corresponding number, measuring each time from U W. Thus make W 7 equal to O 7; the distance from U W to the point 6 equal to P 6; and so continue till all the distances have been measured. A line traced through these points will constitute a profile of the raking portion on a line at right angles to its direction, and B K and C H will be the miter lines. To develop the pattern first lay off the stretch-out of the profile T U V upon any line drawn at right angles to B C, as A¹ B¹. As the points in U T have already been dropped upon the miter lines in the previous process it is now only necessary to place the T-square parallel to A¹ B¹ and, bringing it successively against the points in C H and B K, drop lines cutting the measuring lines of corresponding number. A line traced through the points of intersection, as shown by X X Y Y, will be the pattern of the raking portion B K H C. To this may be added the flat triangular piece K H G, as shown by X Y Z. From the points X and Z lines may be drawn at right angles to X Z, as shown by Z J and X Q, extending them sufficiently to complete the lower portion of this part of the boiler, shown by K E D G of the elevation.

PROBLEM 78.

The Pattern for a Blower for a Grate.

In Fig. 370 D F K H E shows a front view, P L M O a side view, and A C B a plan of a blower. The conditions which determine the course to be pursued in arriving at the pattern are that its upper outline shall conform to the semicircle F K H of the elevation, and that it shall slant from K to G at an angle indicated by the line L M of the profile. Therefore, the first step will be to determine a true section of its

upper portion or hood upon a line at right angles to L M from the point N of the side view; after which,

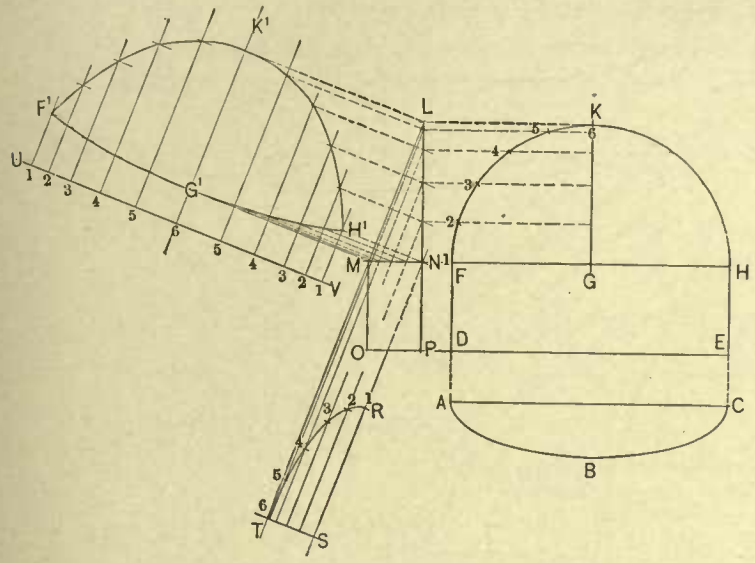


Fig. 370.—Pattern for a Blower for a Grate.

with N M and N L as miter lines, the pattern can be developed in the usual manner. To obtain a true profile of the hood, divide one-half of the semicircle F K H into any number of equal spaces, and carry lines from each of the several points to the vertical line L N of the side view. From the points thus obtained in L N carry lines parallel with L M indefinitely, which intersect at right angles by the line T S, located at any convenient point outside of the diagram. With the dividers take the horizontal distances between the points in the arc F K to the line K G, and set them off on the lines of corresponding number, measuring from the line T S. Then a line drawn through the points thus obtained, and as indicated by T R, will be a correct section through the inclined portion of the blower. Take the stretchout of the profile T R point by point and place the spaces on the line U V, which is drawn at right angles to L M. Through the points in U V draw the usual measuring lines at right angles to it. As the points from the profile T R have already been dropped upon both the miter lines M N and N L, it is only necessary to carry them, at right angles to L M, on to the measuring lines of corresponding numbers. Then a line traced through the points thus obtained, and as indicated by F' K' H', will be the desired pattern.

PROBLEM 79.

Pattern for a Can Boss to Fit Around a Faucet.

In Fig. 371 is shown a top and side view of a boss whose sides are in part parallel and just sufficiently apart to allow the faucet to fit between them. L N represents the diameter of the opening at the top. K L M N represents the general shape of the boss where it joins the can and is the result of the conditions existing in the side view, but is not made use of in the process of obtaining the pattern. The essential points are the curve of the can body, D A B E, the diameter of boss at top, L O N, the distance between D and E and the distance X C, all of which are shown in the side view.

Divide one-quarter of the plan of the top, as indicated by O N, into any convenient number of spaces, as indicated by 1, 2, 3, etc. From the points thus established drop lines vertically, cutting the line representing the top in the side view, as shown from F to C. From the points thus established in F C carry lines parallel to the side F D, producing them until they cut the curved line D A B E, as shown between D and A. The next step to be taken is to obtain the profile which would be shown by a section taken through the article at right angles to the line D F. For this purpose at any convenient point draw a line through D F and at right angles to it, as shown by P R. From the points established in the plan of the top, as shown from O to N, carry lines vertically until they meet the horizontal line K M passing through the cen-

ter of the top, as shown. Taking the length of each of the distances thus obtained in the dividers, set it off from either side of P R on the lines of corresponding numbers, and through the points thus obtained trace the curve, as shown. Then this curve will represent the required section from which the stretchout of the envelope may be obtained. On the line R P, produced sufficiently outside of the side view for the purpose, lay off the stretchout of one-half of this curve, as shown, and through the points thus established draw measuring lines parallel to D F. Then, with the T-square placed parallel to P R, or, what is the same, at right angles to D F, and brought successively against the points in the profile of the can body between D and A, cut the measuring lines of corresponding numbers. In like manner bring the T-square against the points in the top of the article shown from F to C and cut the measuring lines of corresponding numbers. Then lines traced through the points thus obtained, as shown by D′ A′ and F′ C′, will be one-half of the pattern of one of the ends. As that portion of the boss lying between points A, B and C is simply a flat triangular piece it is only necessary to add a duplicate of its shape to that part of the pattern just obtained, bringing one of its straight sides against the line 5, all as shown. To the other straight side C′ B′ must be added a duplicate of the first part of the pattern reversed, as shown by B′ C′ G′ E′; the resulting shape will then constitute the pattern of one-half the boss.

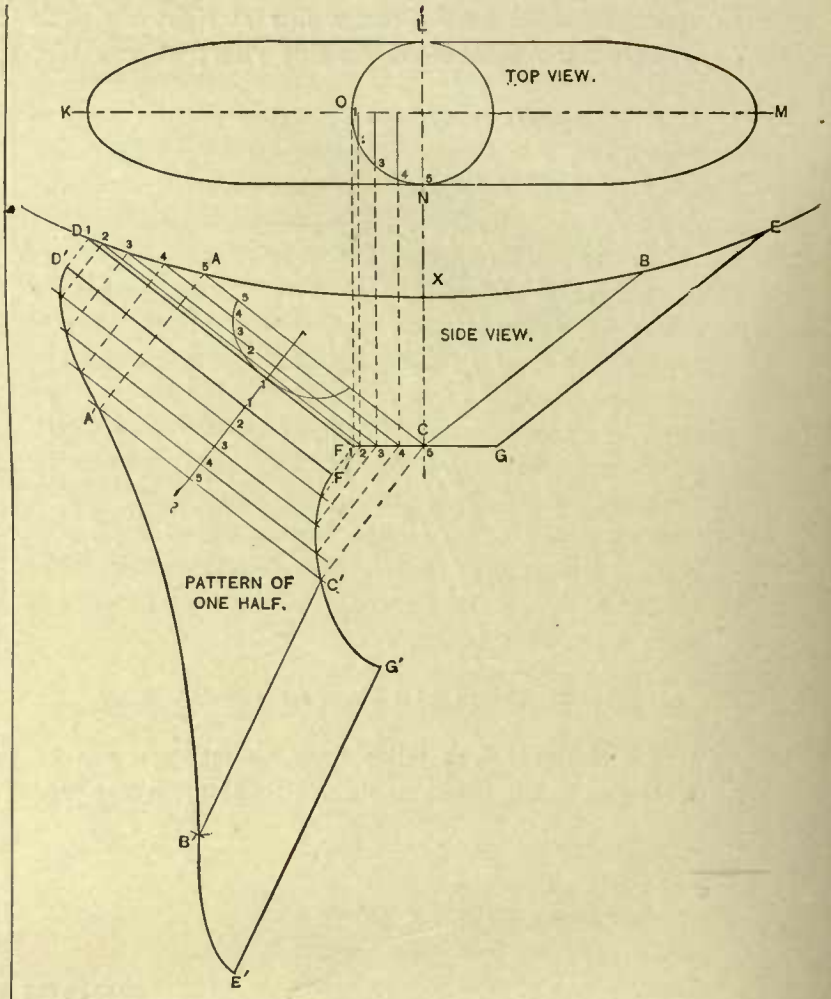


Fig. 371.—Pattern for a Can Boss to Fit Around a Faucet.

PROBLEM 80.

The Patterns for a Molded Base in which the Projection of the Sides is Different from that of the Ends.

Let A B C D, in Fig. 372, represent the side view and E F G H the plan of a base in which the projection of the sides, as shown at O P, is less than that of the ends, as shown at M C. B C and A D show the profile of the ends of the base. As the projection through the sides of the base is less than that of the ends, a profile must be obtained through the side O P in plan, from which to obtain the stretchout in producing the pattern of sides. To obtain the pattern for the end proceed as follows: Divide the profile B C into an equal number of parts, as shown by the small figures, and from the points obtained drop lines at right angles to A B until they intersect the miter lines J F and L G in plan. At right angles to F G draw the line B^2 C^2, upon which place the stretchout of the profile B C, as shown by the small figures, through which draw the usual measuring lines, which intersect with lines of corresponding numbers drawn from the miter lines at right angles to F G. A line traced through these intersections, as shown by J′ L′ G′ F′, will be the required pattern for the end of the base. To obtain the profile through the side proceed as follows: From B in elevation draw the vertical line B M, as shown, and from the divisions on the profile B C draw lines par-

allel to the lines of the moldings until they intersect the line B M, as shown by the small figures. From the intersections obtained on the miter line L G in plan, as before explained, draw lines parallel to H G and extend them indefinitely, cutting the miter line K H, as shown. Upon K L of the plan extended set off B′ M′, the side of the base. To obtain the pattern for the side proceed as follows: At right angles to H G draw the line B^3 N^3, upon which place the stretchout of the profile B′ N′, as shown by the small figures. It will be noticed that the spaces in the profile B′ N′ are unequal, and therefore each must be separately placed on the line

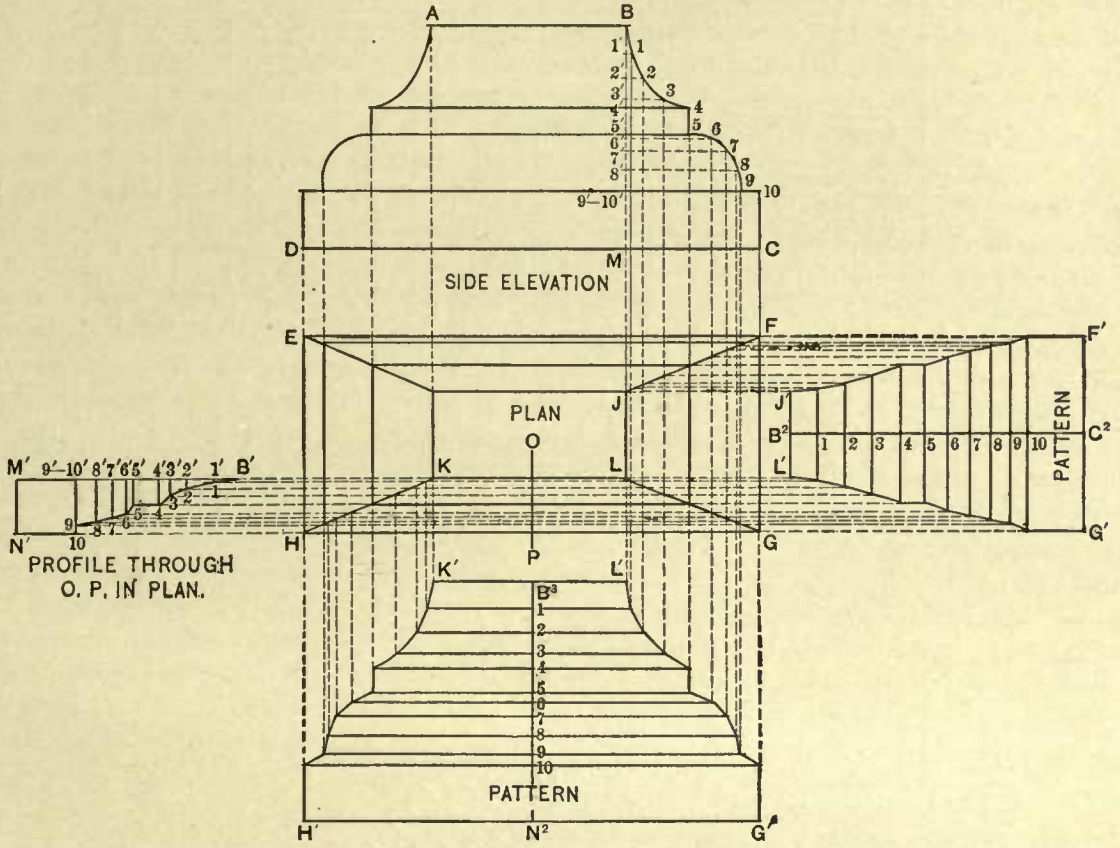


Fig. 372.—The Patterns for a Molded Base in Which the Projection of the Sides is Different from that of the Ends.

in hight equal to B M of elevation, and transfer the spaces from B M to B′ M′, as shown. At right angles to B′ M′ and from the points on same draw lines, as shown, intersecting lines of corresponding numbers drawn from the miter line L G. A line traced through these intersections will be the desired profile through B^3 N^3. Through the points in this stretchout line draw the usual measuring lines, as shown, which intersect with lines of corresponding numbers drawn at right angles to H G from the miter lines K H and L G. A line traced through these intersections, as shown by K′ H′ G′ L′, will be the desired pattern for the side.

PROBLEM 81.

The Patterns for an Elliptical Vase Constructed in Twelve Pieces.

The first essential in beginning the work is an ellipse, which may be drawn by whatever rule is most convenient, and which must be of the length and breadth which the vase is required to have. Draw the plan of the sides of the vase about the curve, as shown in Fig. 373, in such a manner that all the points X, Y, Z, etc., shall have the same projection beyond the curve. Complete at least one-fourth of the plan by drawing miter lines, as shown by P C, M C, O C, U C and N C. Above the plan construct an elevation of

the article, as shown by H L K G. Only the profile H V W L of the elevation is needed for the purpose of pattern cutting, but the other lines are desirable in process of designing, in order that the effect may be considered before the article is constructed. As the projection of each of the sides upon the plan is different when measured from the center C on lines at right angles to the lines of the sides, it will be necessary

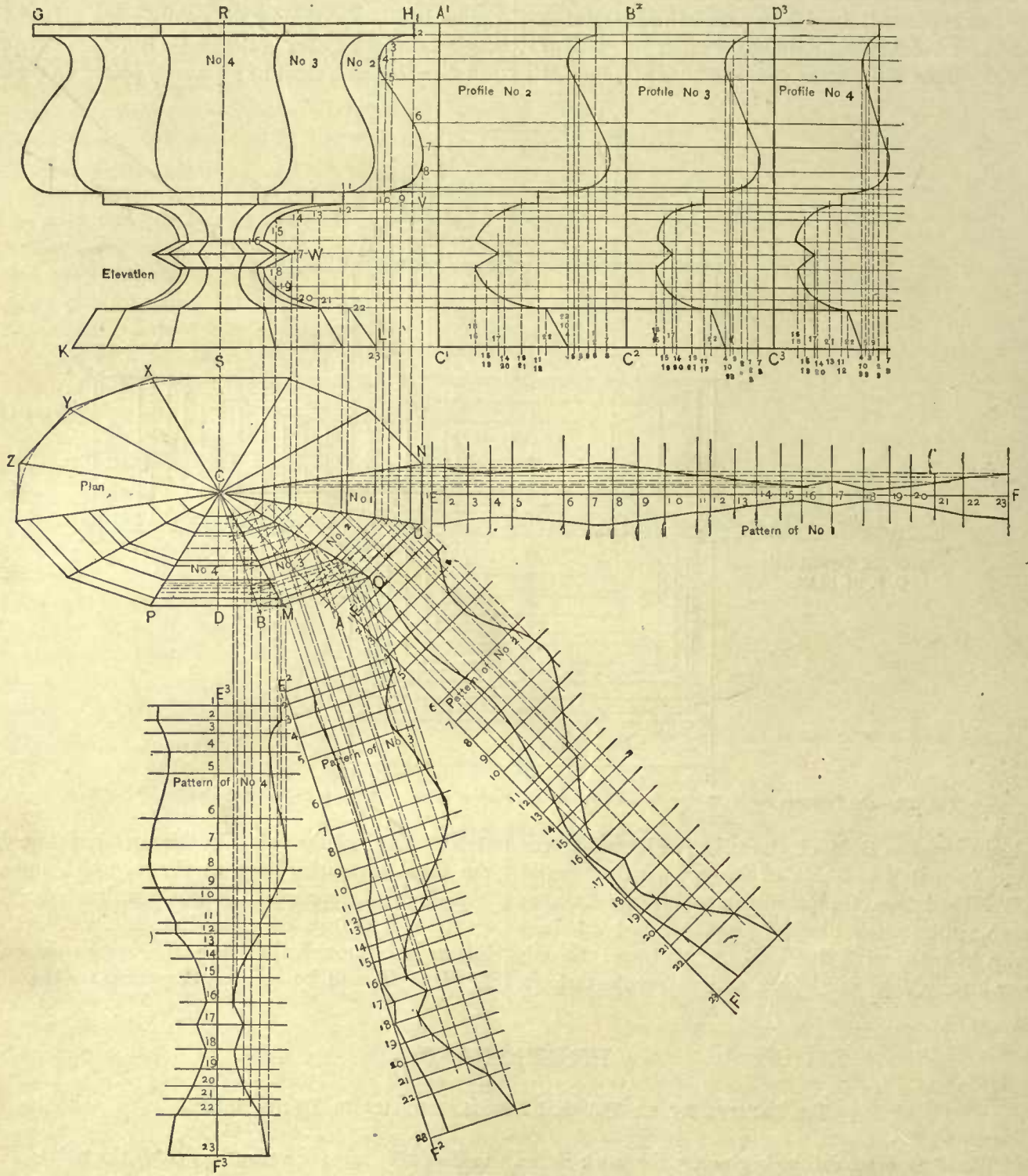


Fig. 373.—The Patterns for an Elliptical Vase Constructed in Twelve Pieces.

first to develop the profiles of each of the varying sides from the normal profile H V W L. Therefore, divide H V W L in the usual manner, and from the several points in it drop lines across its corresponding section (No. 1) of the plan.

Across the second section in the plan, from the points already obtained in U C, draw lines parallel to O U, the side of it cutting O C, and produce them until they meet A C, which is drawn from C at right angles to U O produced. Then the points in A C give the projections from which to obtain a profile of the section numbered 2. In like manner continue the points from C O across the third section in the plan, parallel to O M, the side of it cutting M C, and produce them until they cut C B, which is drawn from C at right angles to O M produced. Then C B contains the points requisite in obtaining a profile of the third section. Continue the points in C M across the fourth section, cutting its other miter line C P. From C draw C D at right angles to the side P M of the section, cutting the lines drawn across section 4. Then upon C D will be found the points necessary to determine the profile of the fourth pattern. Produce the line of the base of the elevation indefinitely, as shown by C^1 C^2 C^3, and also the line of the top A^1 B^2 D^3. From the several points in the profile H V W L draw lines indefinitely, parallel to the lines just described and as shown in the diagram. From C^1, upon the base line produced, set off points corresponding to the points in C A of the plan, making the distance from C^1 in each instance the same as the distance from C in the plan. Number the points to correspond with the numbers given to the points in the profile H V W L, from which they were derived. In like manner from C^2 set off points corresponding to the points in C B of the plan, numbering them as above described. From C^3 set off points corresponding to those in C D of the plan, likewise identifying them by figures in order to facilitate the next operation. From C^1 erect the perpendicular C^1 A^1; likewise from C^2 and C^3 erect the perpendiculars C^2 B^2 and C^3 D^3. From each of the points laid off from C^1, and also from each of those laid off from C^2 and C^3, erect a perpendicular, producing it until it meets the horizontal line drawn from the profile H V W L of corresponding number. Then lines traced through these several intersections will complete the profiles, as shown. Perpendicular to the side of each section in the plan lay off a stretchout taken from the profile corresponding to it, just described, and through the points in the stretchouts draw measuring lines in the usual manner, all as shown by E F, E^1 F^1, E^2 F^2 and E^3 F^3. Place the T-square parallel to each of these stretchout lines in turn, and, bringing it against the several points in the miter lines bounding the sections of the plan to which they correspond, cut the measuring lines in the usual manner. Then lines traced through the points of intersection thus obtained, all as shown in the diagram, will complete the patterns.

PROBLEM 82.

The Patterns for a Finial, the Plan of which is an Irregular Polygon.

In the central portion of Fig. 374 is shown the plan B C D E F G H, upon which it is required to construct a finial, the only other view given being a section through one of the sides, being that numbered 1 on the plan.

The section of side A B C, or No. 1, is shown above and in line with the plan of the same, and is marked Profile No. 1, and is a section on the line A M, which is drawn at right angles to B C of the plan. To obtain the pattern of A B C of plan, or No. 1, divide the profile K L in the usual manner, and, with the T-square placed parallel with C B of plan and brought successively against the several points in profile K L, drop lines cutting the miter lines A B and A C.

On A M extended, as A1 M1, lay off a stretchout of K L of profile, through the points in which draw the customary measuring lines. Place the T-square parallel to the stretchout line A1 M1, and, bringing it against the several points in the miter lines A B and A C, cut corresponding measuring lines. Tracing lines through the points thus obtained, as shown by

A1 C1 B1, will give the pattern of part of article shown on plan by A B C.

at right angles to each—that is, since A N, A O and A P, drawn at right angles respectively to C D, D E

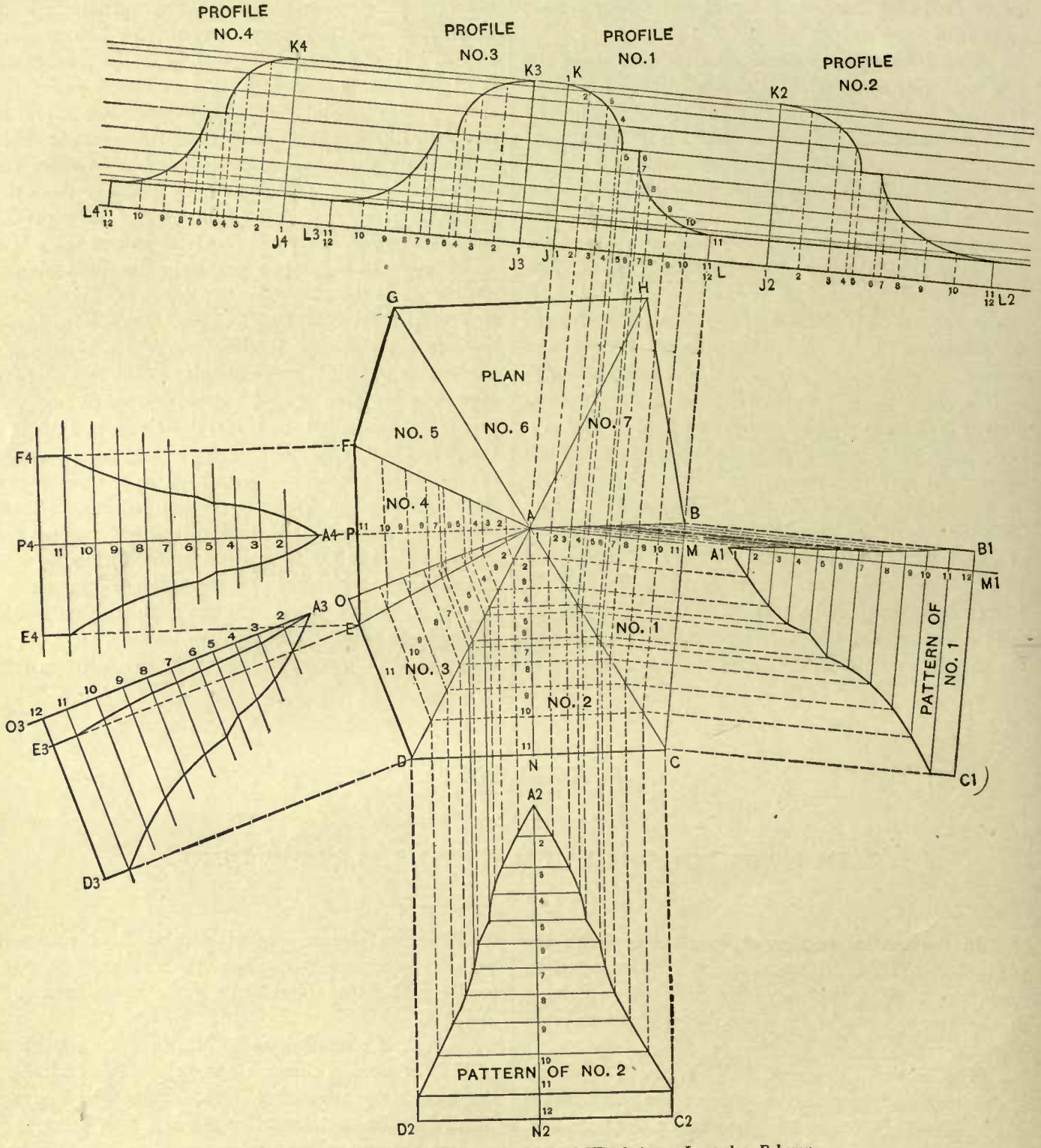


Fig. 374.—Pattern for a Finial, the Plan of Which is an Irregular Polygon.

Since the point A in the plan is not equidistant from all the sides of the same, when measured on lines

and E F, differ in length from each other and from A M—a correct section must be obtained for each

of the other sides before their patterns can be developed.

These different sections can be most conveniently obtained at one operation in the following manner:

With the T-square placed parallel with D C, and brought successively against the points in A C, draw lines cutting A D and A N. Then the points in A N can be used to obtain a profile of section No. 2. Also continue the points from A D across the third section of the plan, and parallel with D E, and produce them until they cut A E, also A O, which is drawn from A at right angles to D O produced. Then A O contains the points necessary in obtaining a profile of the third section. Continue the points from A E across the fourth section of the plan, and parallel with E F, cutting A P and A F. Then the points in A P can be used to obtain a profile of section No. 4.

While the projection of the several points in each of the new profiles can be obtained respectively from the lines A N, A O and A P, the hights of the several points must be the same in all and must be derived from the normal profile K L. Therefore continue J L, which represents a horizontal line of profile No. 1, in either direction, as shown by L4 L2. From the several points in profile No. 1 draw lines parallel with L4 L2, extending them indefinitely in either direction. At any convenient position on L4 L2 set off points corresponding to the points in A N of the plan, as shown at J2 L2, numbering them to correspond with the points in A N and in the normal profile. From each of the points in J2 L2 erect lines perpendicular to the same, intersecting lines of corresponding number drawn from K L. Then a line traced through the points of intersection, as shown from K2 to L2, will be the correct section on A N of the plan, from which to obtain a stretchout of piece No. 2.

The sections of pieces No. 3 and No. 4 are obtained in a similar manner from A O and A P. J3 L3 is a duplicate of A O and J4 34 of A P. Perpendiculars are erected from each of the points cutting horizontal lines of corresponding number, thus developing K3 L3 and K4 L4.

To obtain the pattern of A D C (No. 2) continue A N downward indefinitely, upon which lay off a stretchout of K2 L2, as shown by A2 N2, through the points in which draw the usual measuring lines. Place the T-square parallel with A2 N2, and, bringing it against the several points in A C and A D, cut measuring lines of corresponding numbers. Lines traced through these points, as shown by A2 C2 and by A2 D2, will be the pattern sought.

The stretchouts for pieces Nos. 3 and 4 are taken respectively from profiles 3 and 4. A3 O3 is the stretchout of K3 L3 and is laid off on a continuation of A O, while A4 P4 is taken from K4 L4 and is set off on a continuation of A P. The remaining operations are the same as those employed in obtaining the other pieces.

PROBLEM 83.

Pattern for a Three-Piece Elbow, the Middle Piece Being a Gore.

Let A B C D E F G in Fig. 375 be the elevation of a three-piece elbow to any given angle, as G F E, the middle piece of which, B C H, forms a gore extending around one-half the diameter. The lines H B and H C are drawn parallel respectively to the ends of the two outer pieces, therefore the patterns for the end pieces will be straight from H to C and H to B and mitered from H to F. To obtain the pattern for one of the ends, as F H C D E, divide N K L into any convenient number of equal parts. With the T-square at right angles to N L, carry lines from the points in N K L, cutting the miter line F H C, as shown. On any line, as E D extended, lay off a stretchout of N K L, as shown by *e d*, through the points in which draw the usual measuring lines, as shown. With the T-square brought successively against the points in F H C, cut corresponding measuring lines, as shown. A line traced through the points of intersection, as shown by *f h'' c*, will be the half pattern of end, as represented in elevation by F H C D E, or in profile by N K L. The other half of the pattern can be obtained by duplication.

Since H C is drawn parallel to E D, the distance H J is less than one-half the diameter of the normal profile, or less than O L, therefore it will be necessary before obtaining the pattern of B H C to obtain a correct section on line H J of elevation. To do this, first place the T-square parallel with B C and carry lines from the points in H C, cutting H J and H B. Next draw any line, as K′ M′ of the section, and erect the perpendicular H′ J′. From H′, on H′ J′, set off the spaces in H J of elevation, transferring them point by point. Through the points thus obtained draw lines parallel with K′ M′, as shown. With the dividers take the distance across K O L or L O M, on the several lines drawn parallel with K M, and set off the same distance on lines of corresponding number drawn through H′ J′. Thus H′ M′ and H′ K′ are the same as O K and O M. A line traced through the points thus obtained, as shown by K′ J′ M′, will be the section desired.

For the pattern of H B C, lay off on H J extended, as *h h′*, a stretchout of K′ J′ M′ of section, through which draw the usual measuring lines. With the T-square placed parallel with H J, and brought successively against the points in B H and C H, cut corresponding measuring lines drawn through *h h′*, as indicated by the dotted lines. Lines drawn through these points of intersection, as shown by *h b h′ c*, will be the pattern of the part shown in elevation by B H C.

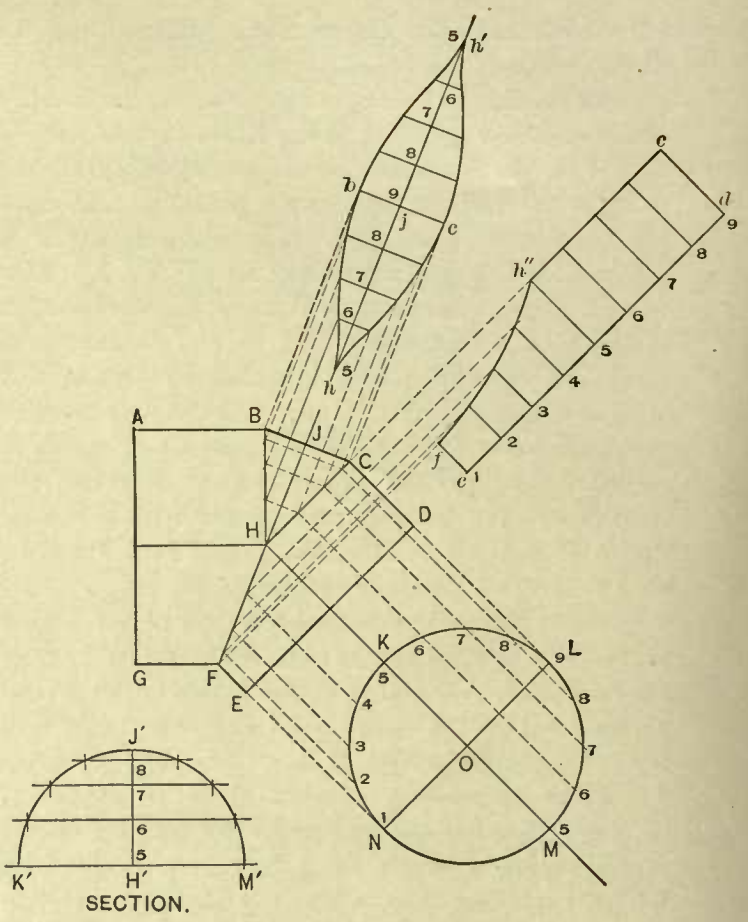


Fig. 375.—Pattern for a Three-Piece Elbow, the Middle Piece Being a Gore.

PROBLEM 84.

The Patterns of a Tapering Article which is Square at the Base and Octagonal at the Top.

A B D C in Fig. 376 shows the plan of the article at the base, I K L M H G F E represents the shape at the top, E^3 H^3 D^3 C^3 is an elevation of one side. In order to obtain the slant hight of the octagonal sides it will be necessary to construct a diagonal section or elevation. Therefore extend the lines of the base C^3 D^3 and top E^3 H^3, as shown, to the left, through which draw a vertical line, as R^1 C^2. Upon the line of the base set off each way from C^2 a distance equal to A R or R D of the plan. In like manner upon the line of the top, set off from R^1 each way a distance equal to one-half I G. Draw I^1 A^1 and G^1 D^1, thus completing a diagonal section. If it is desired to complete a diagonal elevation, set off E^2 F^2 equal to E F of the plan and draw lines to C^2, as shown.

To obtain the pattern of one of the smaller sides, produce the diagonal line R C, upon which set off the length or stretchout of I^1 A^1, as shown by N C^1, and draw the measuring line E^1 F^1. By means of the T-square, as indicated by the dotted lines, set off E^1 F^1 equal to E F of the plan and draw C^1 E^1 and C^1 F^1. Then E^1 C^1 F^1 is the pattern of one of the smaller sides

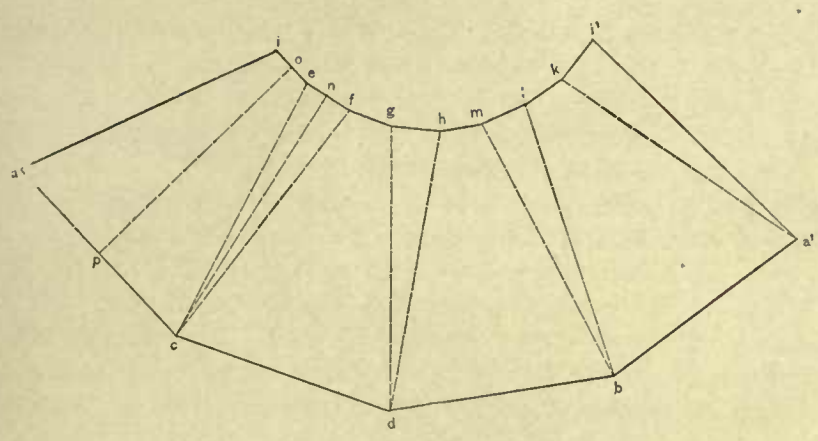


Fig. 377.—Pattern in One Piece.

of the article. For the pattern of one of the larger sides, draw R P perpendicular to the side A C, upon which set off O P, in length equal to E^3 C^3 of the elevation, at right angles to which through O and P draw measuring lines.

By means of the T-square, as shown by the dotted lines, make A^2 C^4 equal to A C of the plan. In like manner make I^2 E^4 equal to I E of the plan. Connect A^2 I^2 and C^4 E^4. Then A^2 I^2 E^4 C^4 will be the pattern of one of the larger sides of the article. If for any reason the pattern is desired to be all in one piece the shapes of the different sides may be laid off adjacent to each other, the large and small sides alternating, all as indicated by *i i' a a'*, Fig. 377.

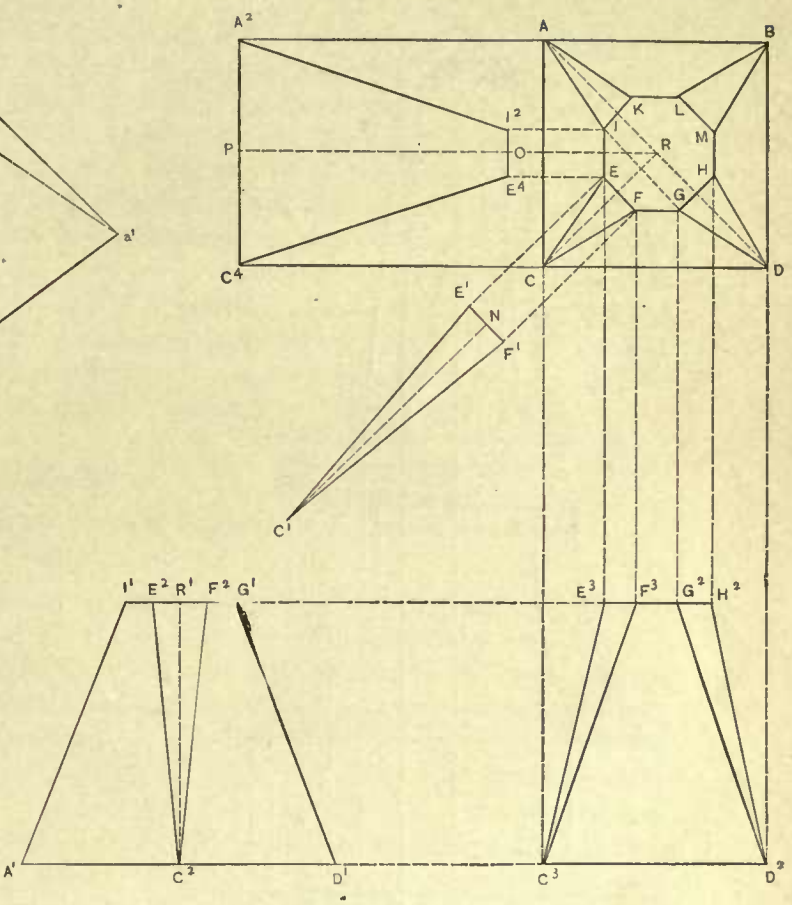


Fig. 376.—Elevations, Plan and Patterns.

A Tapering Article Which is Square at the Base and Octagonal at the Top.

PROBLEM 85.

The Patterns of a Finial, the Plan of which is Octagon with Alternate Long and Short Sides.

In Fig. 378, let A L M N O P R S T be the elevation of the finial corresponding to the plan which is shown immediately below it. The elevation is so drawn as to show the profile of one of the long sides, for the pattern of which proceed in the usual manner. Divide the profile A L M N O P into any number of convenient spaces, as shown by the small figures, and from the points thus obtained drop lines across the corresponding section in the plan, cutting the miter lines D E C and D^2 F C, as shown. A duplicate of the part E C F of the plan is shown below by E' C^2 F', and in the demonstration C^2 E' and C^2 F' are to be considered the same in all respects as C E and C F. The same may be said of the two parts of the stretchout line bearing like letters; the division having been made on account of the extreme length which the pattern would have if made in one piece. Perpendicular to D D^2 lay off a stretchout, as shown by G H, through the points in which draw measuring lines in the usual manner. Place the T-square parallel to the stretchout line, and, bringing it against each of the several points in D E C and D^2 F C, cut the corresponding measuring lines. Then a line traced through these points of intersection will be the pattern sought.

For the pattern of the short sides a somewhat different course is to be pursued. As the distance from C to the line K E is greater than that from C to E F a profile of the piece as it would appear if cut on the line C D must first be obtained. To do this proceed as follows: From the points in C E, dropped from the

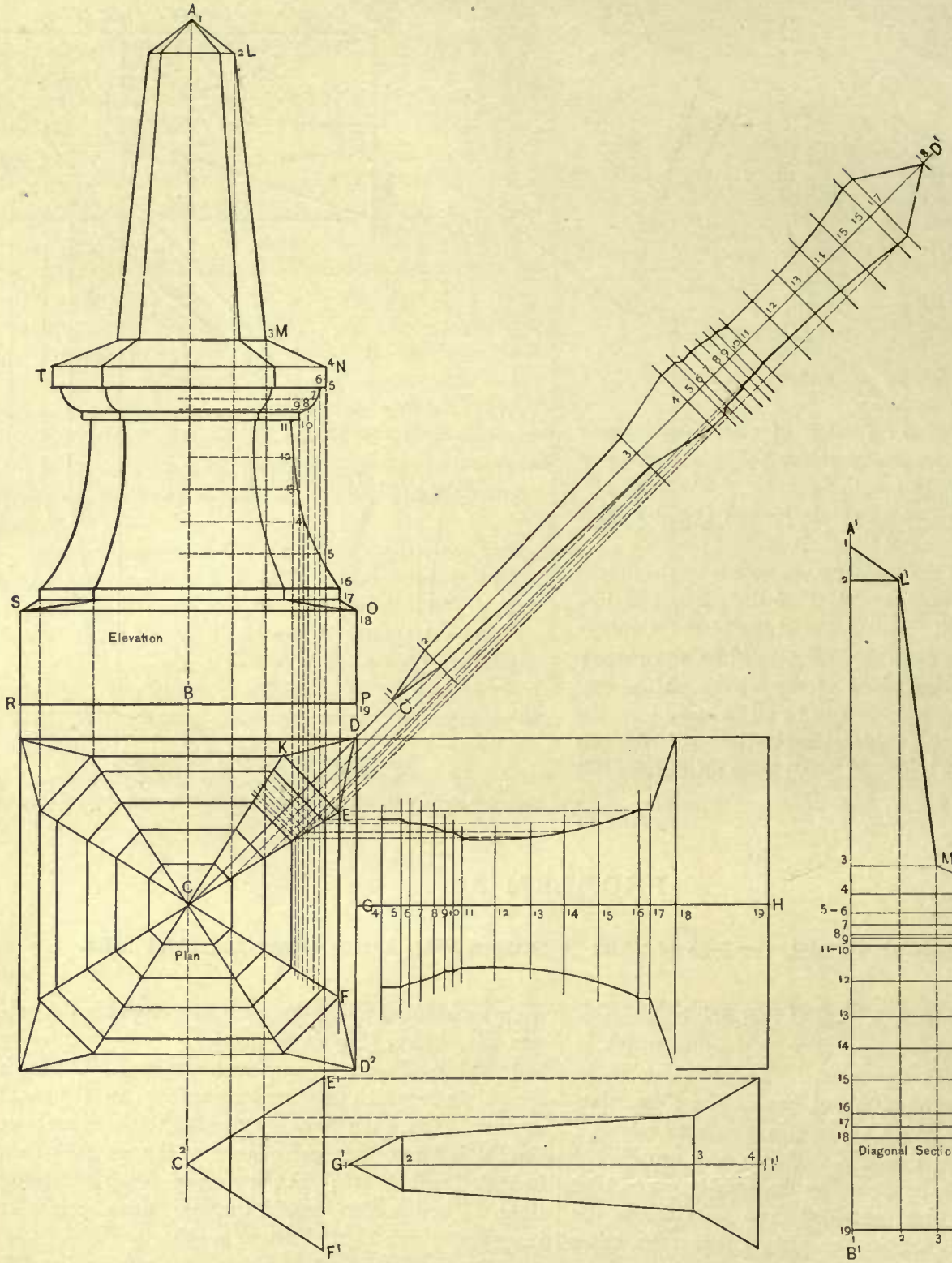


Fig. 378.—Elevation, Plan and Patterns.

Fig. 379.—Diagonal Section.

The Patterns of a Finial, the Plan of Which is Octagon with Alternate Long and Short Sides.

profile, carry lines parallel to E K across C D, cutting C K, as shown. At any convenient place lay off B' P', Fig. 379, in length equal to C D of the plan, on which lay off points corresponding to the points obtained in C D, and for convenience in the succeeding operations number them to correspond with the num-

bers in the profile from which they are derived. At B' erect the perpendicular B' A', equal to B A of the elevation. From the several points in the profile of the elevation draw horizontal lines cutting the central vertical line A B, as shown. Set off points in A' B' in Fig. 379 to correspond, and through these points draw horizontal lines, which number for convenience of identification in the following steps. From the several points in B' P' carry lines vertically, intersecting corresponding horizontal lines. Then a line traced through these points, as shown by A' L' M' N' O' P', will be the profile of the short side on the line C D of the plan. After obtaining the profile as here described, for the pattern of the short side proceed as follows: Perpendicular to K E of the short side, or on C D extended, lay off a stretchout of the diagonal section A' O' of Fig. 379, as shown by C' D', through the points in which draw measuring lines in the usual manner. Place the T-square parallel to the stretchout line, and, bringing it against the several points in the miter lines D K C and D E C bounding the short side in the plan, cut the corresponding measuring lines. Then a line traced through these points, as shown in the diagram, will be the required pattern.

PROBLEM 86.

The Pattern for a Gore Piece Forming a Transition from an Octagon to a Square, as at the End of a Chamfer.

In Fig. 380, let F F F F represent the plan of the square portion of a shaft and A A A A that of the

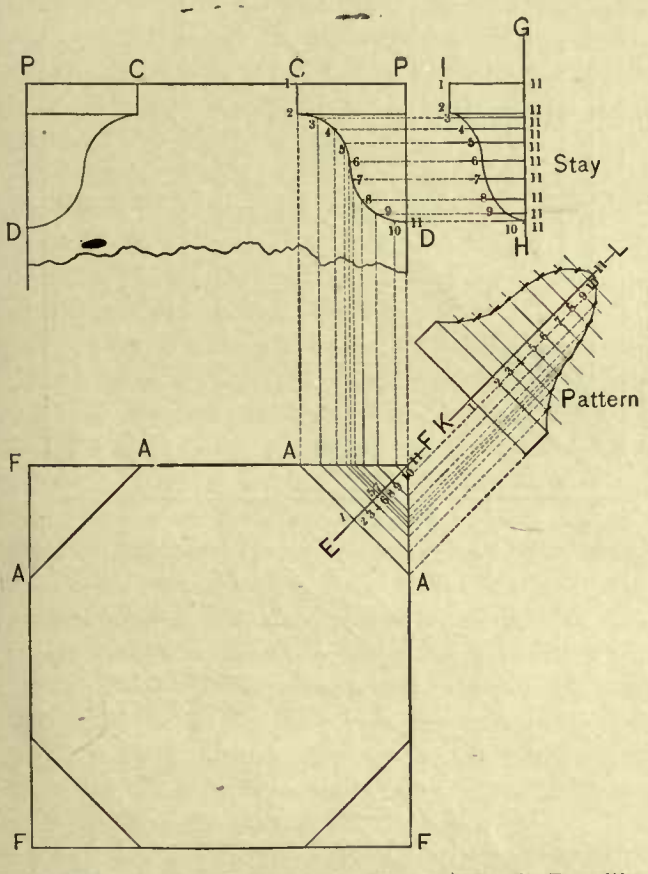


Fig. 380.—The Pattern for a Gore Piece Forming the Transition from an Octagon to a Square.

octagon portion. Let D P C be the elevation of the gore piece which is required to form the transition between the two shapes. The outline C D, which represents the intersection of the gore piece with the side of the shaft, may be of any contour whatever at the pleasure of the designer, the method of laying out the pattern being the same no matter what its outline. By reference to the plan it will be seen that the lines of the molding, of which C D shows only the termination, run octogonally, or in the direction of A A. Therefore, before a stretchout of the piece can be obtained a correct profile must be developed on a line at right angles to its lines—that is, on the line E F. To do this proceed as follows: Divide the line C D, as it appears in the elevation, into any convenient number of spaces, as shown by 1, 2, 3, 4, etc. From the points thus obtained drop lines down upon the side of the plan A F, which should be placed in line below the elevation.

Continue the lines from the side A F across the corner, as shown, all parallel to A A of the octagon, crossing E F, and number the lines to correspond with the numbers of the points in the elevation from which they were derived. Draw the vertical line G H at a convenient distance from P D, and cut G H by lines drawn at right angles to it from the points in C D, as shown by the connecting dotted lines. G H then may be considered to represent the point F in the plan, or 11 of the numbers on the line E F. From G H, on each of the several lines drawn through it, lay off a distance equal to the space from E to the corresponding number in the same plan. Thus lay off from G H on line 1 a distance equal to 11 1 on E F, and on line 2 a distance equal to 11 2 of E F, and so on for each of the lines through G H. Then a line traced through these points, as shown by I H, will be the

profile of the gore piece, or the shape of its section when cut by the line E F.

Prolong E F, as shown by K L, and lay off on the latter a stretchout of the profile I H, the spaces of which must be taken from point to point as they occur, so as to have points in the stretchout corresponding to the points on the miter lines A F, previously derived from C D. Through the points thus obtained draw the usual measuring lines, as shown. Place the T-square at right angles to the measuring lines, or, what is the same, parallel to E F, and, bringing it against the points in A F and F A, cut the corresponding lines drawn through the stretchout. Lines traced through these points, as shown, will constitute the pattern.

PROBLEM 87.

The Pattern for a Gore Piece in a Molded Article, Forming a Transition from a Square to an Octagon.

In Fig. 381, let A B D C represent the elevation of an article of which G H I J is the half plan at the base and K L M N O P the half plan at the top. A C of the elevation is the normal profile or profile of one of the square sides, and L H and M H of the plan show the miter lines between the square sides and the gore piece. C E and D F, the elevations of the miter lines H M and I N, are shown as part of the design, but are not necessary in cutting the pattern.

As only the normal profile, which would be used in cutting the pattern of one of the square sides, is shown in the elevation, the first step will be to obtain from this a profile of the gore piece, or in other words, a section upon its center line, R H of the plan. Divide the profile A C into any convenient number of parts, and from the points obtained drop lines at right angles to A B, cutting the miter line L H in plan, as shown. From the intersections obtained on the miter line L H draw lines parallel to L M, as shown, cutting the other miter line H M, and continue them indefinitely. At any convenient position outside the plan draw the line A^1 A^2 parallel to H R, and draw a duplicate of the profile A C in the same relative position to A^1 A^2 that A C holds to A B, and divide the same into the same spaces as A C, all as shown by A^1 C^1. From the points in A^1 C^1 draw lines parallel to A^1 A^2, cutting lines of corresponding number drawn through the plan of the gore piece. A line traced through these intersections, as shown from A^2 to C^2, will be the profile of the transition piece from which to obtain the stretchout for the pattern.

To obtain the pattern proceed as follows: Upon R^1 R^2, a continuation of H R, place the stretchout of the profile A^2 C^2, as shown by the small figures, through which draw the measuring lines, as shown. These are now to be intersected by lines drawn from points of corresponding number upon the miter lines H L and H M. Lines traced through the points of intersection, shown by R T and R S, will give the desired pattern.

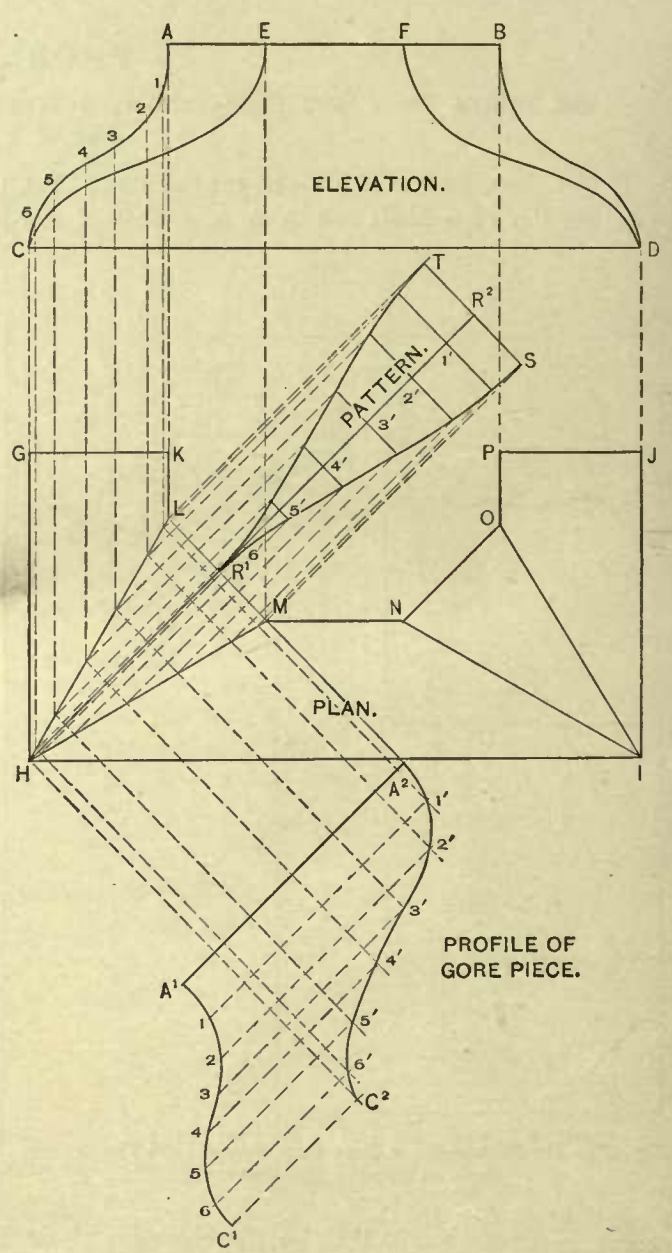


Fig. 381.—The Pattern for a Gore Piece in a Molded Article, Forming a Transition from a Square to an Octagon.

PROBLEM 88.

The Patterns for a Raking Bracket.

This is one of the many instances which calls for special draftsmanship on the part of the pattern cutter. Frequently the architect's drawings give only a detail of a bracket for the level cornice of a building, while the scale elevations show one or more of the gables to be finished with raking brackets. In such cases the detail of the "level" bracket and the pitch of the roof are the only available facts from which to produce the required bracket.

In Fig. 382, let M X or O P be drawn at the required angle, with reference to any horizontal line, to represent the pitch of the gable cornice. The first step is to redraw the normal side elevation of the level bracket so that its vertical lines shall be at right angles to the lines of the rake, all as shown at L Q P. Next, at any convenient distance from this draw two *vertical* lines, as M O and X^1 P^1, the horizontal distance between which shall be the required face width of the bracket. Lines projected parallel to the rake from the various angles in the profile between these vertical lines will complete the front elevation of the raking bracket. The additional lines E G and F H representing the sink in the face, A C showing the depth of the panel in side, and U D giving the depth of the sink in the face, will be understood from the drawing.

To construct a side view of the raking bracket, or, what is the same thing, the pattern for the side (including the bottom of the sunken panel and the sink strips U D Z in the face), all hights must be measured upon one of the vertical lines of the face view, as M O. To avoid confusion, however, and make room for other patterns, another vertical line, X^1 P^2, will serve as well. Divide the curved portions U to P of the face of the normal profile into any convenient number of small spaces for use in this and subsequent parts of the operation. From all the points in the profile of face carry lines parallel to the rake through the side view and continue them till they intersect the vertical line X^1 P^2. From the points thus obtained in the line X^1 P^2 carry lines indefinitely horizontally, as indicated. Upon each of the lines so drawn lay off from the line X^1 P^2 a distance or distances equal to the distance or distances upon the corresponding lines drawn across the normal side of the bracket. Through the points thus obtained trace lines, which will give the several shapes in the sides of the brackets corresponding to the shapes shown in the side of the normal bracket. It may be necessary to introduce in the several profiles of the normal bracket other points than those derived from spacing the profile. Use as many such points as may be necessary to determine the position of all points in the side being constructed. Then X^1 N^2 P^2 will be the pattern of the side of the bracket, and U^2 Z^2 D^2 will be the pattern of the strip forming the sides of the sink shown in the face by E F H G, and b^1 a^1 d^1 c^1 will be the shape of the panel in the side of the bracket.

For the patterns of the several pieces forming the face of the bracket the profiles are to be found in the normal side view, from which stretchouts can be obtained when wanted, and laid out at right angles to the lines of the rake; while the miter lines of any part are the vertical lines of the face view corresponding to that part of the profile under consideration.

For the strip R E G S, forming that part of the face at the side of the sink, lay off a stretchout of its profile U Z at right angles to the lines of the rake, as shown by u^2 z^1, through the points in which the usual measuring lines are drawn. Drop the points from the profile to the miter lines R S and E G; then, with the T-square placed at right angles to the lines of the rake, and brought successively against the points in R S and E G, the corresponding measuring lines are cut. Then lines traced through these points of intersection, as shown by R^1 S^1 and E^1 G^2, form the pattern for that piece.

For the piece forming the face of the bracket below the sink, as shown in the elevation by S O P^1 Z^1, proceed in like manner. A stretchout of its profile, as indicated by D P, is laid off at right angles to the lines of the rake, through which the usual measuring lines are drawn. The points in D P are then carried parallel to the rake, cutting the miter lines S O and Z^1 P^1. The T-square is then placed at right angles to the lines of the rake, and brought against the several points in the sides S O and Z^1 P^1, by which the corresponding measuring lines are cut. In like manner it is brought against the points G and H, by which the shape of the part extending up to meet the sink is determined. Then lines traced through these several points of intersection, as shown by H^2 Z^3 P^3 O^1 S^2 G^4, form the pattern for that part of the face of the bracket. The upper part of the face of the bracket, shown in the face view

by N' U' R M, being a flat surface, as indicated in the side view N U, is obtained by pricking directly from the face view of the bracket, no development of it being necessary.

To avoid confusion of lines, the sink piece E F H G is transferred to the right, as shown by E' F' H' G'. The profile of it, as indicated in the side view by U D, is divided into any convenient number of spaces, and through the points lines are drawn, cutting the miter lines E' G' and F' H'. The stretchout of this profile, as shown by u^1 d^2, is laid off at right angles to the lines of the rake, and through the points in it the usual measuring lines are drawn. The T-square is then placed at right angles to the lines of the rake, and, being brought successively against the points in the sides E' G' and F' H', the corresponding measuring lines are cut. Then lines traced through these points of intersection, as shown by E² G² F² H², constitute the pattern of the bottom of the sink.

Of the strips bounding the panel of the side in the

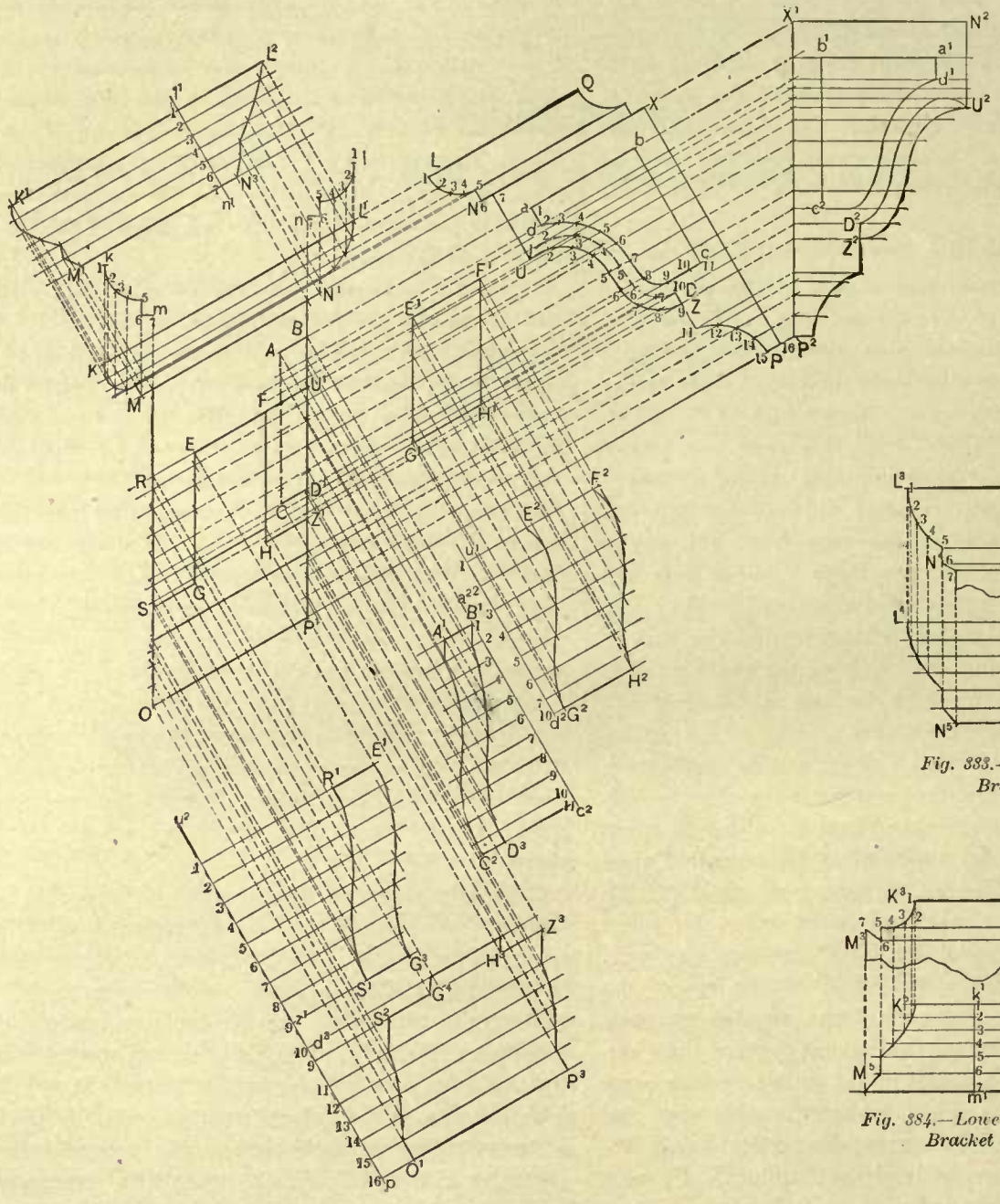


Fig. 382.—The Patterns for a Raking Bracket.

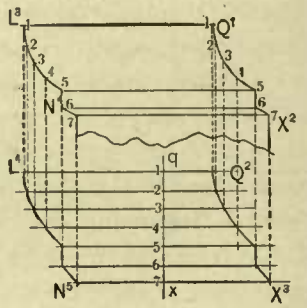


Fig. 383.—Upper Return of Bracket Head.

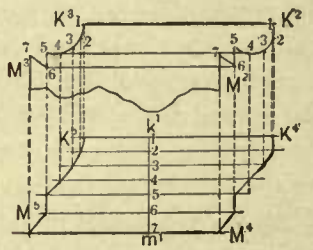


Fig. 384.—Lower Return of Bracket Head.

bracket, the piece corresponding to *b c* in the side view, being vertical, is obtained by pricking directly from its elevation in the face view of the bracket, A B D' C being the shape. For the other straight strip bounding this panel, shown in the side view by *a b*, the length is laid off equal to *a b*, while the width is taken from the face view, equal to the space indicated by A B. For the strip representing the irregular part *a* to *c* proceed as follows: Divide the profile *a d c* into any convenient number of parts, from the points in which carry lines crossing the face view of the same part, as indicated by A B D' C. At right angles to the lines of the rake lay off a stretchout of the profile just named, as indicated by a^2 c^2, through the points in which draw the usual measuring lines. Place the T-square at right angles to the lines of rake, and, bringing it against the several points in the line A C and B D', cut the corresponding measuring lines drawn through the stretchout. Then lines traced through the several points of intersection thus formed, as indicated by A^1 C^2 and B^1 D^2, will be the pattern of the curved strip forming part of the boundary of the panel in the side view of the bracket.

Of the three pieces of molding forming the head of the bracket, the profile of the piece across the face is normal, as shown at L N, while that of the two side pieces, or returns, requires to be modified or raked before a square miter with the face piece can be effected. These principles will be further explained in Problems 91 to 94. The first step will be to draw a correct elevation of the head, which includes raking the profiles of the upper and lower returns.

Divide the normal profile L N into convenient spaces, and from the points thus obtained carry lines indefinitely parallel to the rake across the top of the face view of the bracket. Draw duplicates of the normal profile, placing them in a vertical position directly above where the new sides are required to be, as shown by *n l* and *k m*. Divide these two profiles into the same number of parts employed in dividing the normal profile, and from these points drop lines vertically, intersecting those drawn from L N. Then lines traced through these points of intersection, as shown by L' N^1 and K M, will be respectively the profiles of the moldings on the upper side and on the lower side of the bracket. Lay off a stretchout of the profile L N at right angles to the line of the rake and through the points in it draw the usual measuring lines. With the blade of the T-square at right angles to the lines of the rake, and brought successively against the several points in the profile N^1 L' and K M, cut the measuring lines drawn through the stretchout. Then lines traced through the points of intersection thus obtained, as shown by L^2 N^2 and K^1 M^1, will be the shape of the ends of the molding forming the front of the bracket head.

Before laying out the pattern for the return molding forming the upper side of the bracket head a correct side elevation of it must be drawn. A duplicate of the profile L^1 N^1 is transferred to any convenient place, as shown at L^3 N^4 in Fig. 383, and parallel lines from its angles are extended to the right, as shown, making L^3 Q^1 equal to L Q of the side view of the bracket.

At Q^1 repeat the outline L^3 N^4, which represents the intersection of the bracket head with the bed mold of the cornice. L^1 N^1 of Fig. 382 is then the correct profile and the lines L^3 N^4 and Q^1 X^2 are the miter lines of this return; however, as both the miter lines are identical with the profile, the stretchout *q x* may be taken from either one, the other being divided into the same number of spaces as the first, which is easier than dropping the points from one to the other. The T-square may then be placed at right angles to the lines in the molding and brought successively against the points in the lines L^3 N^4 and Q^1 X^2, and the corresponding measuring lines intersected. Then lines traced through these points, as shown by L^4 N^5 and Q^2 X^3, will form the pattern.

The pattern for the return molding of the head occurring on the lower side of the bracket is obtained in the same manner. A duplicate of the profile K M of the face view of the bracket is drawn at any convenient place, as shown by K^2 M^2 in Fig. 384. The proper length is given to the molding by measuring upon the side view of the bracket, and a duplicate of the profile is drawn at the opposite end. Space the profile K^2 M^2 into any convenient number of parts, as indicated by the small figures, and in like manner divide the profile K^3 M^3 into the same number of parts. At right angles to the line of the molding lay off a stretchout of these profiles, as shown by k^1 m^1, through which draw the usual measuring lines. With the blade of the T-square at right angles to the lines of the molding, and brought successively against the several points in the profiles K^2 M^2 and K^3 M^3, cut the corresponding measuring lines. Then a line traced through these points of intersection, as shown by K^5 M^5 and K^4 M^4, will constitute the pattern of the return molding, or the lower side of the bracket.

PROBLEM 89.

The Pattern for a Raised Panel on the Face of a Raking Bracket.

In the solution of the problem stated above, and which is given in Fig. 385, the first requisite is the design or outline of the side of the normal bracket, as such an outline is really a section through the raking bracket upon a line at right angles to the rake. N S T shows the side view of a normal bracket, or the bracket as it would appear in a level cornice, the part from G to H being molded as shown by the shaded profile, which profile, being a section on line *a b* of the normal bracket, is given complete at J and called the normal profile. The first step is to derive from these factors a front elevation of the molded panel upon the face of the raking bracket. To accomplish this first divide the profile of the panel molding into any convenient number of equal parts, as shown in the section shaded in the side of the normal bracket, and through these points draw lines parallel to the face of the bracket, producing them until they cut the upper surface against which the panel terminates, and in the opposite direction until they meet the vertical surface in the lower part of the bracket against which the panel terminates at the bottom. From the points thus obtained in the horizontal surface near the top of the bracket and in the vertical surface near the bottom of the bracket draw lines at right angles to the face, thus transferring the points to the line representing the outer face of the panel, as shown from G to H.

These points will be used a little later in developing the view of the panel at right angles to the face. Next, from the points already obtained in the line representing the vertical surface near the bottom of the bracket carry lines parallel with the rake, extending them across the front elevation of the bracket. In the diagram, to avoid confusion, these lines terminate at the intersections shown from A to B, but in actual work they would be extended across the front elevation, thereby making also the intersections shown from C to D. At any convenient place in line with the front elevation of the raking bracket draw the normal profile, as shown below the elevation, and divide it into spaces corresponding to the spaces used in dividing the profile in the side view. From the points thus obtained carry lines vertically, intersecting those just drawn from the side of the normal bracket across the front elevation. A line traced through the points of intersection gives the outlines shown at A B and C D. These outlines constitute a front elevation of the lower end of the molded panel, or the view as seen from a point exactly in front of the face of the raking bracket when finished and in its proper or final position. The outline or shape of the upper end of the panel would appear as a simple straight line in this view because it miters against a surface which is horizontal from front to back. A B C D F E shows the entire front view of the molded panel. This view furnishes the means for the next step, which is to obtain a view at right angles to the face G H, and at the same at right angles to the lines of the rake N O. To do this, first continue the lines from the normal profile of panel in their vertical course till they intersect the upper line of the panel E F. These lines are omitted through the face of the bracket, the points only being indicated on the line E F. From the points thus established in E F, and from the points derived in the outlines A B and C D, carry lines at right angles to the raking cornice, producing them indefinitely, as shown. At right angles to the raking cornice, at any convenient place, draw the line H' and G', setting off on it spaces corresponding to those established in H G, already described. Through the points in H' G' draw lines at right angles to it to the left, producing them until they intersect lines already drawn from the outlines A B and C D and the points in the line E F. Through the points of intersection thus obtained, as indicated by 1 7 in the lower left hand corner, 8 14 in the lower right hand corner, 8, 9, 10, etc., in the upper right hand corner, and 1, 2, 3, 4, etc., in the upper left hand corner, trace lines, thus completing a view of the panel piece at right angles to its face. The next step to be taken is to develop a true profile of this panel, or in other words, a section at right angles to its lines, from which to obtain a stretchout for the required pattern. To do this, first assume any line, as P O, at right angles to the lines of the view just obtained as the surface of the panel in the new profile. Upon this line extended, as at K, draw a duplicate of normal profile so that the points 7 and 8 shall lie in it. Divide the profile K into the same number of spaces as in previous instances, and from these points carry lines through the face view intersecting them with lines of corresponding number, as

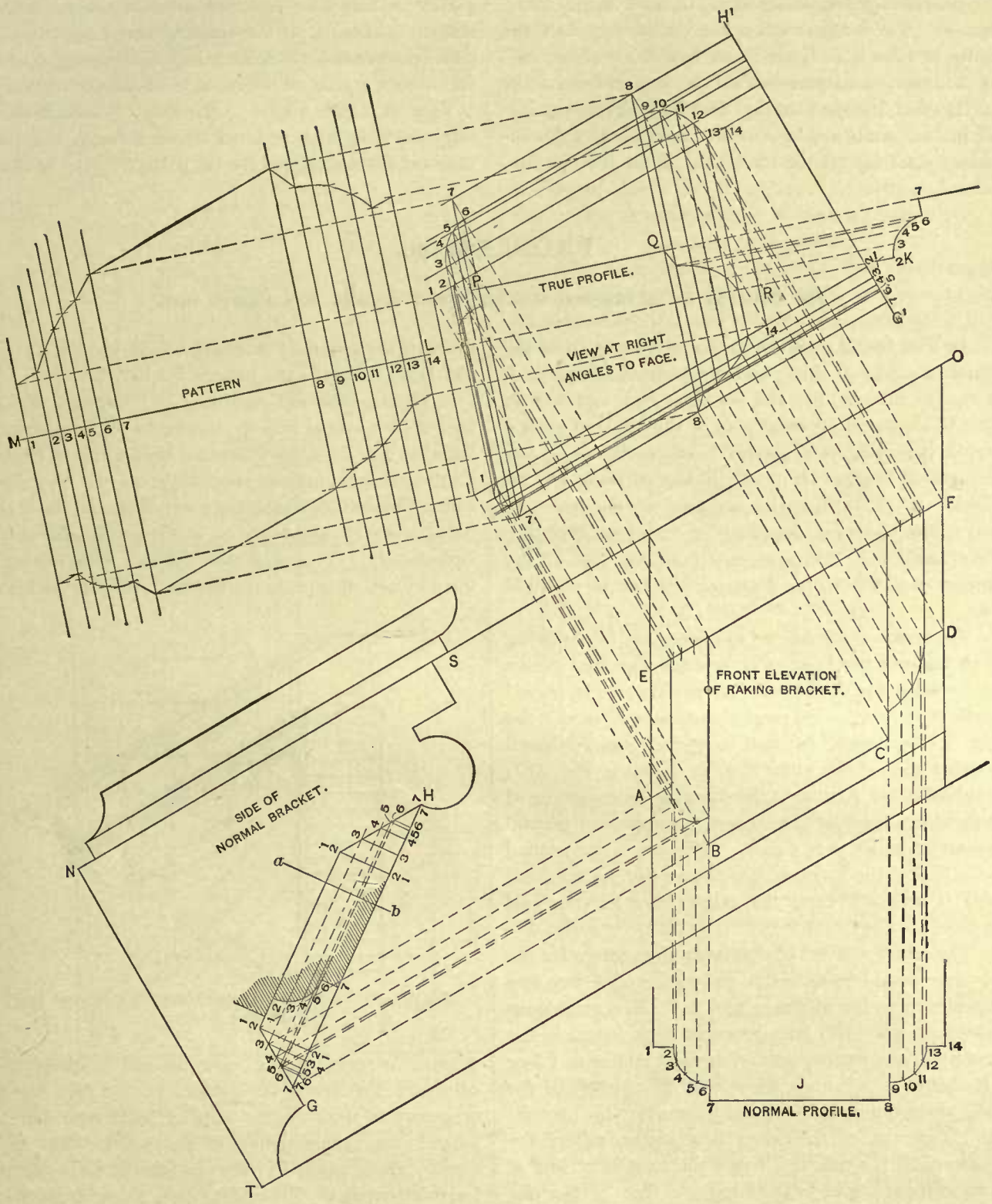


Fig. 385.—The Pattern for a Raised Panel on the Face of a Raking Bracket.

shown at L P and Q R. Then L P Q R will be the true profile of the moldings along the face of the raking bracket. The student will observe that only half the profile is shown at K, as both halves are alike, one-half will answer all purposes if it be kept in mind while making the intersections by number that the points 1–7 in one profile are 14–8 in the other. At any convenient place lay off the stretchout of the true profile, as shown to the left by the line L M. Through the points in this line draw the usual measuring lines, as shown. Then, with the blade of the T-square placed parallel with the stretchout line and brought against the several points of intersection at the corners of the "View at Right Angles to the Face," cut corresponding measuring lines. Lines traced through the points thus obtained will produce the pattern shape, as shown.

PROBLEM 90.

The Patterns for a Diagonal Bracket Under Cornice of a Hipped Roof.

In Fig. 386 is shown a constructive section of the cornice of a hipped roof, under which the bracket L fits against the planceer and over the bed molding C. Fig. 387 shows an inverted plan of the angle of such a cornice, including two normal brackets B and C, and the diagonal bracket D, of which the patterns are required. At A, in line with one arm of the cornice in plan, is also shown a duplicate of the profile of the normal bracket. E F represents the miter line of the planceer over which the diagonal bracket is required to fit.

Two distinct operations are necessary in obtaining the patterns of the bracket D, one for the face pieces and the other for the sides. As the bracket is placed exactly over (or more properly speaking under) the miter in the cornice, one-half its width must be drawn on either side of the miter line, as shown in Fig. 387. Each half of its face thus becomes a continuation of the moldings forming the faces of the course of normal brackets of which it is a part. Therefore the normal profile X 8 of the bracket A is the profile to be used, and I G and J F form the miter lines for one half the face.

The usual method in obtaining the pattern for the face piece would be to divide the profile of A into any convenient number of spaces and lay off a stretchout of the same upon any line drawn at right angles to the direction of the mold—that is, at right angles to I J or G F—after which lines should be dropped from the profile upon the miter lines and thence into the stretchout. However, as the miter is a square miter, the short method is available; hence the stretchout line is drawn at right angles to the horizontal line of the elevation X X, as shown at H G. The usual measuring lines are drawn and interseeted with lines from points of corresponding number on the profile. Lines traced through the points of intersection, as shown by K M and L N, will give the pattern for half the face.

The operation of obtaining or "raking" the pattern of the side is exactly similar to that employed in Problem 88, with the difference that while in Problem 88 the side is elongated vertically, in the present instance (the cornice remaining horizontal, and the bracket being placed obliquely) it is elongated laterally or horizontally. The operation is also complicated by the addition of a profile at the back edge of the bracket

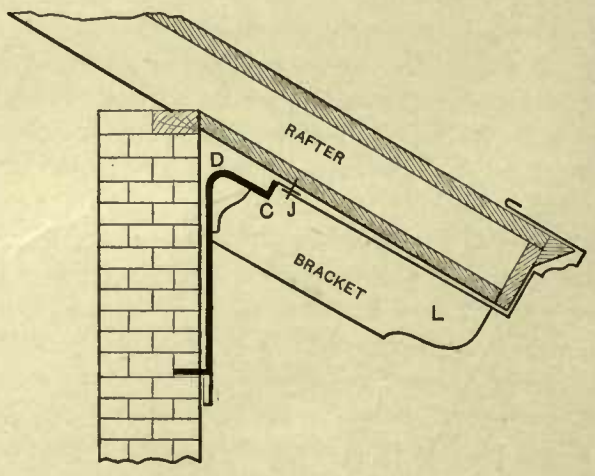


Fig. 386.—Sectional View of the Cornice of a Hipped Roof, Showing Bracket.

where it is required to fit over the bed molding of the cornice. To obtain the pattern of the side it is first necessary to ascertain the correct horizontal distances between the various points of the profile. The points already made use of in obtaining the face may be used for this purpose. Therefore, drop lines from each of these points vertically, intersecting the side of the bracket, or, what is the same thing, the center line E F, as shown in the plan, Fig. 387, by 1′, 2′, 3′, etc. The

profile at the back of the bracket in the elevation must also be divided into a convenient number of spaces, as shown by the small figures, which must also be dropped upon E F, as shown, and numbered correspondingly.

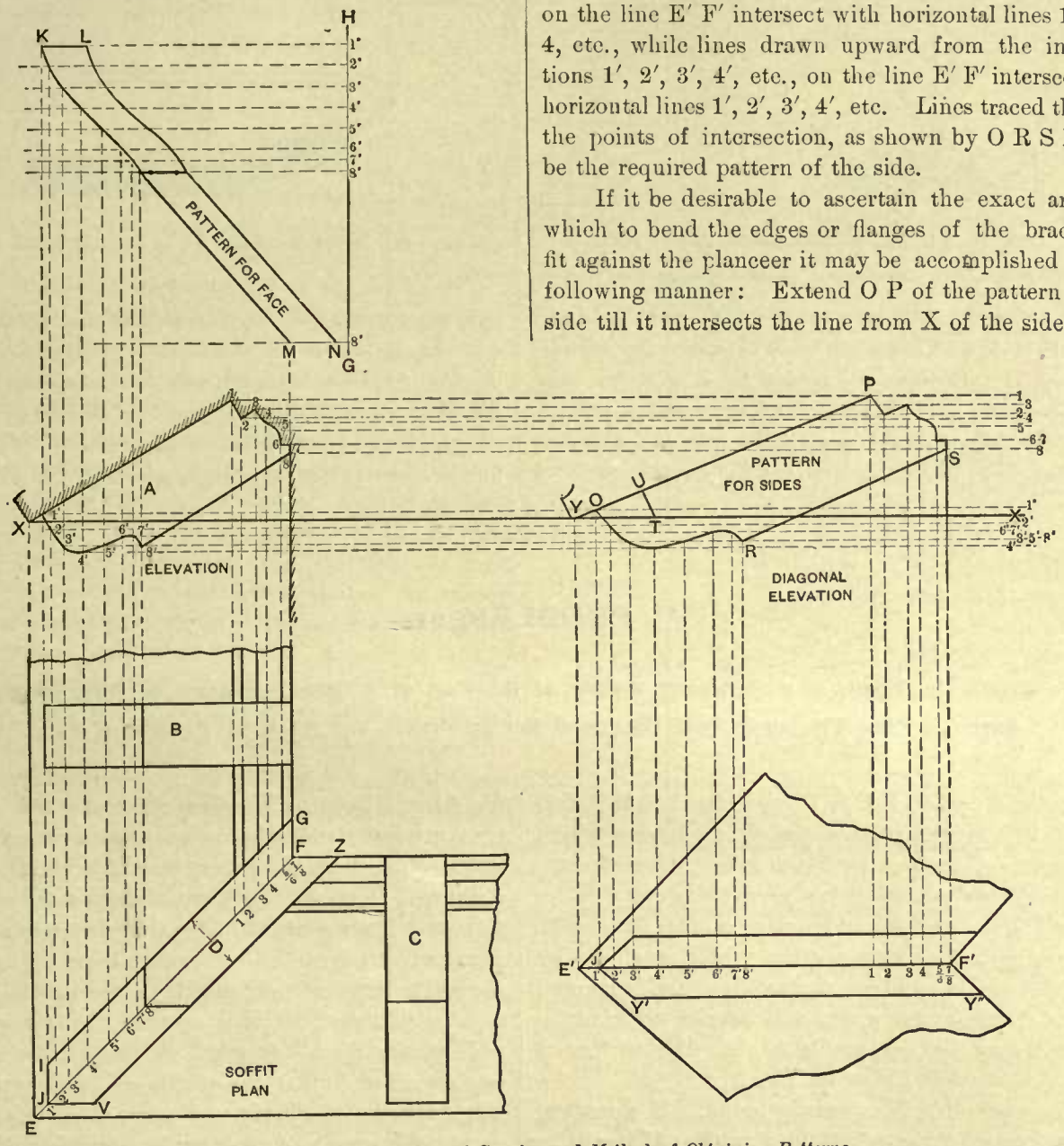


Fig. 387.—Inverted Plan of Cornice and Method of Obtaining Patterns.

From each of the points in the profile of the elevation carry lines indefinitely to the right, as shown. At any convenient point at the right of the plan, draw another plan of the diagonal bracket, so placed that its sides shall be parallel with the horizontal line X X of the elevation, all as shown, and upon its center line E′ F′ transfer the points and spaces from E F. Low from each point in the line E′ F′, erect lines vertically, intersecting lines of corresponding number previously drawn to the right from the elevation. Thus, lines drawn upward from the intersections 1, 2, 3, 4, etc., on the line E′ F′ intersect with horizontal lines 1, 2, 3, 4, etc., while lines drawn upward from the intersections 1′, 2′, 3′, 4′, etc., on the line E′ F′ intersect with horizontal lines 1′, 2′, 3′, 4′, etc. Lines traced through the points of intersection, as shown by O R S P, will be the required pattern of the side.

If it be desirable to ascertain the exact angle to which to bend the edges or flanges of the bracket to fit against the planceer it may be accomplished in the following manner: Extend O P of the pattern of the side till it intersects the line from X of the side elevation, as shown at Y. Upon the solid line X X in diagonal elevation establish any point, as T. Through the point T and at right angles to Y P draw a line intersecting the line Y P at U.

As the angle of the plan shown in Fig. 387 is a right angle, construct a right angle, A B C, Fig. 388,

and bisect it, obtaining the miter line B L. Now take the distance from Y to T in diagonal elevation, and place it on the miter line B L in Fig. 388, from B to D. At right angles to B L draw a line through the point D, intersecting the sides of the right angle A B C at E and F. Now take the distance T U in diagonal elevation and set it off from D toward B, locating the point H. Connect the points E, H and F; then will the profile E H F in Fig. 388 represent a section across the hip at right angle to its rake and will also be the angle to be used in putting the straight parts of the face together, as shown by E′ H′ F′ in Fig. 389. The angle which the sides of the bracket make with the planeeer will be the complement of the angle H E D of Fig. 388 and may be obtained as follows: Parallel to B L, in Fig. 388, and through the point E, draw I K, representing the vertical side of the bracket; then will the angle J E I represent the profile required for bending the flanges on the side of the bracket, the profile being shown in position by I′ E′ J′ in Fig. 389.

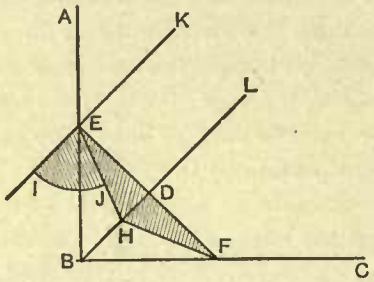


Fig. 388.—Diagram for Obtaining Angles for Bending the Flanges.

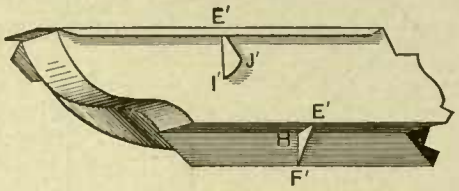


Fig. 389.—Perspective View of Finished Bracket.

In Fig. 389 is shown a perspective view of the finished bracket as seen from below.

PROBLEM 91.

To Obtain the Profile of a Horizontal Return, at the Foot of a Gable, Necessary to Miter at Right Angles in Plan With an Inclined Molding of Normal Profile, and the Miter Patterns of Both.

In the elevation B C E D, and plan F G H K L I, of Fig. 390 is presented a set of conditions which necessitate a change of profile in either the horizontal or raking molding, in order to accomplish a miter joint at I H in the plan. In other words, the conditions are such that with a given profile, as shown by A′, in the raking molding, the profile of the horizontal molding forming the return will require to be modified, as shown by the profile A², in order to form a miter upon the line I H in the plan.

The reason for this is easily found. If a vertical line be erected from point 9 in profile A² it will be seen that each line emanating from a point in the normal profile A′ becomes depressed after passing this vertical line, more or less, according as its distance away from this line increases, all in proportion to the amount of rake or incline of the face molding, as shown by the dotted lines. If, on the contrary, the profile A² be considered as the normal profile, the profile A′ will have to be changed or "raked," in this case increased in hight, in proportion to the inclination. (These conditions are treated in the succeeding problem.) The vertical hight of the profile of the return may be measured in the side elevation and compared with that of the inclined molding by measuring across the latter at right angles to the line B C.

In this problem it is assumed that the profile as well as the pitch, or rake, of the cornice B C are established and that the profile of the horizontal return is to be modified, or "raked," to suit it. To obtain this profile, first draw the normal profile in the raking cornice, as shown by A′, placing it to correspond to the lines of the cornice, as shown. Draw another profile corresponding to it in all parts, directly above or below the foot of the raking cornice, in line with the face of the new profile to be constructed, placing this profile A so that its vertical lines shall correspond with the vertical lines of the horizontal cor-

nice. Divide the profiles A and A' into the same number of parts, and through the points thus obtained draw lines, those from A' being parallel to the lines of the raking cornice, and those from A intersecting them vertically. Through these points of intersection of like numbers trace a line, which gives the modified profile, as shown by A^2. Then A^2 is the profile of the horizontal return, indicated by G H I F in the plan. It is also the elevation of the miter line I H of the plan. Therefore at any convenient point at right angles to the lines of the raking cornice lay off the stretchout M N of the profile A', through the points in which draw measuring lines in the usual manner. Place the T-square at right angles to the lines of the raking cornice, and, bringing it successively against the points in the profile A^2, cut the corresponding measuring lines just described. Through the points of intersection trace a line, as shown by O P R. Then O P R will be the shape of the lower end of the raking cornice mitering against the return. For the pattern of the return proceed as follows: Construct a side elevation of the return, as shown by S V U T, making the profile V U the same as the profile A^2 of the elevation. Let the length of the return correspond to the return, as shown in the plan by F I. In the profile V U set off points corresponding to the points in the profile A^2 as shown from B to D. At right angles to the elevation of the return lay off a stretchout of V U, or, what is the same, of the profile A^2, as shown by W X, through the points in which draw measuring lines in the usual manner. Placing the T-square parallel to this stretchout line, and bringing it successively against the points in V U, cut the corresponding measuring lines. Then a line traced through these points of intersection, as usual, from Y to Z, will be the pattern of the horizontal return.

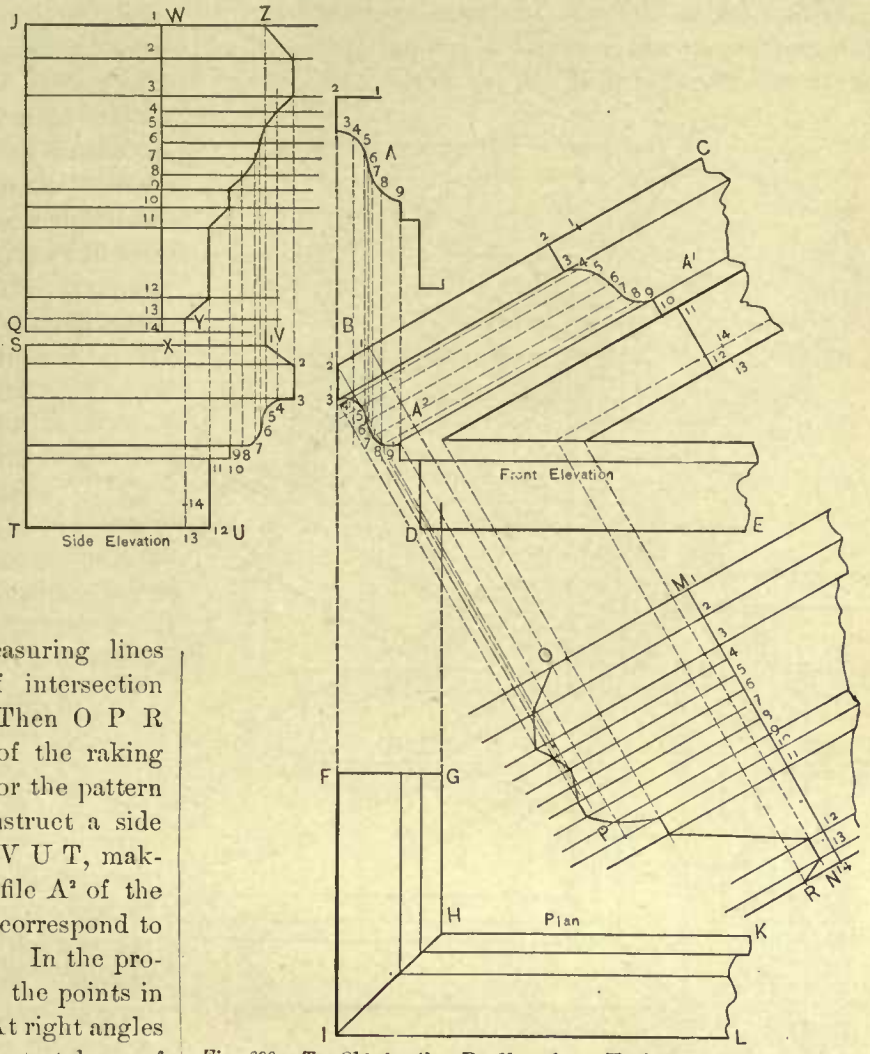


Fig. 390.—To Obtain the Profile of a Horizontal Return at the Foot of a Gable, Necessary to Miter at Right Angles in Plan with an Inclined Molding of Normal Profile, and the Patterns of Both.

PROBLEM 92.

To Obtain the Profile of an Inclined Molding Necessary to Miter at Right Angles in Plan with a Given Horizontal Return, and the Miter Patterns of Both.

The conditions shown in this problem are similar to those in the one just demonstrated. In this, however, the normal profile is given to the horizontal return, and the profile or the raking cornice is modified to correspond with it. To obtain the new profile proceed as follows: Divide the normal profile A', Fig. 391, into any convenient number of parts in the usual manner, and from these points carry lines parallel to

the lines of the raking cornice indefinitely. At any convenient point outside of the raking cornice, and at right angles to its lines, construct a duplicate of the normal profile, as shown by A², which divide into like number of spaces. With the T-square at right angles to the lines of the raking cornice, and brought successively against the several points in this profile, cut corresponding lines drawn through the cornice from the profile A'. Then a line traced through these points of intersection, as shown by A², will be the profile of the raking cornice. For the pattern of the foot of the raking cornice mitering against the return, take the stretchout of the profile A² and lay it off on any line at right angles to the raking cornice, as shown by P O. Through the points in this stretchout line draw the usual measuring lines, as shown. With the T-square at right angles to the lines of the raking cornice, or parallel to the stretchout line, bring it successively against the points in the profile A', which is also an elevation of the miter, and cut the measuring lines drawn through the stretchout P O. Then a line traced through the points of intersection, as shown by B' R', will be the miter pattern of the foot of the raking cornice.

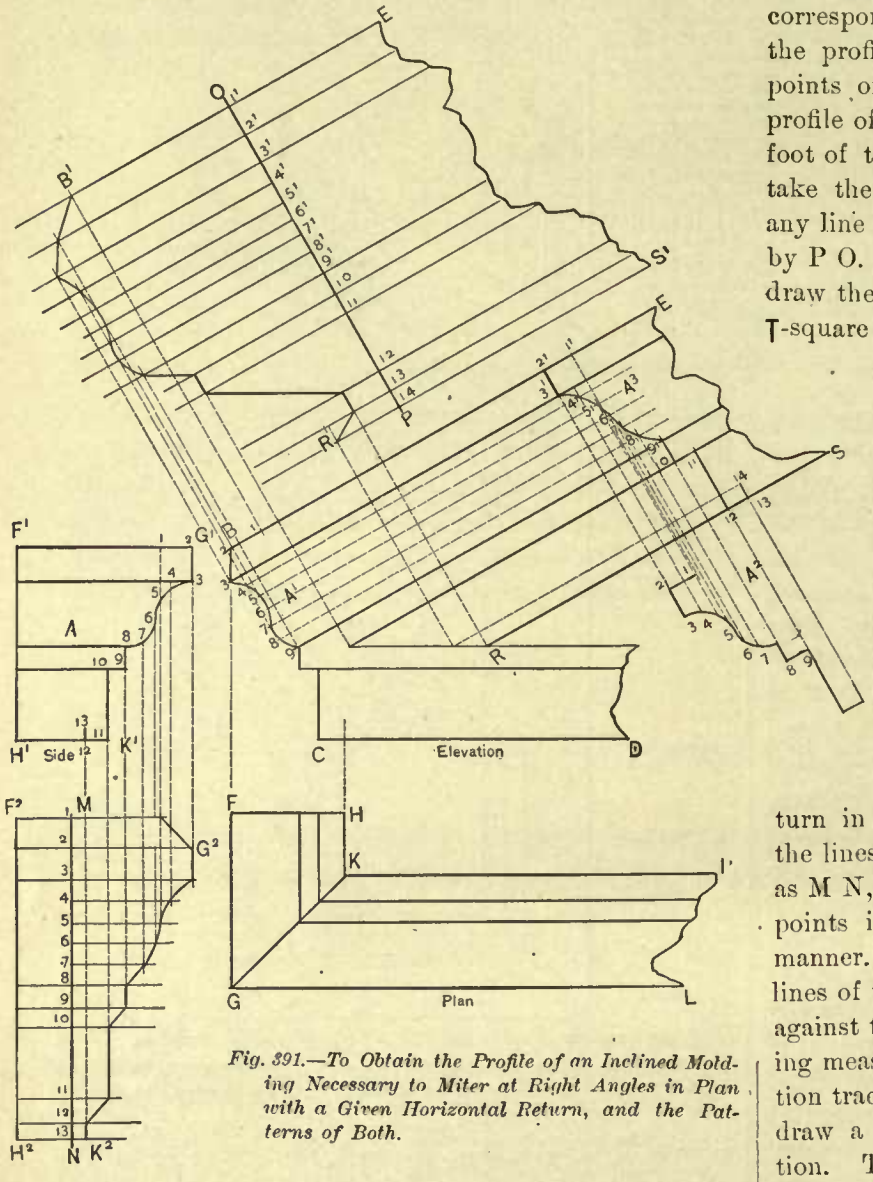


Fig. 391.—To Obtain the Profile of an Inclined Molding Necessary to Miter at Right Angles in Plan with a Given Horizontal Return, and the Patterns of Both.

For the pattern of the return proceed as follows: Construct an elevation of the return, as shown by F' G' K' H', in dimensions making it correspond to F G K H of the plan. Space the profile A of the return in the same manner as A'. At right angles to the lines in the return cornice draw any straight line, as M N, on which lay off its stretchout, through the points in which draw measuring lines in the usual manner. Place the T-square at right angles to the lines of the return cornice, and, bringing it successively against the points in the profile A, cut the corresponding measuring lines. Through the points of intersection trace a line, as shown by G² K². In like manner draw a line corresponding to F' H' of the side elevation. Then F² G² K² H² will be the pattern of the horizontal return to miter with the raking cornice, as described.

PROBLEM 93.

To Obtain the Profile of the Horizontal Return at the Top of a Broken Pediment Necessary to Miter with a Given Inclined Molding, and the Patterns of Both.

In Fig. 392, C B D represents a portion of the elevation of what is known as a "broken pediment," the normal profile of whose cornice is shown at A'. With these conditions existing it becomes necessary to obtain new profiles for the returns at both the top and the foot. The method of raking the return at the foot has been described in Problem 91, and the method of raking the return at the top is exactly the same. If,

in the designing of the pediment, the normal profile should be placed in the return at the foot, as is sometimes necessary, then the profile of the inclined molding must be first obtained, which in turn must be considered as a normal profile and used as a basis of obtaining the third profile, that of the return at the top.

In Fig. 392, let A^1 be considered as the normal profile of the inclined molding. Divide A^1 into any convenient number of parts in the usual manner, and through these points draw lines parallel to the lines of the cornice indefinitely. At any convenient point outside of the cornice, and in a vertical line with the point at which the new profile is to be constructed, draw a duplicate of the profile of the raking cornice, as shown by A, which space into the same number of parts as A^1, already described. From the points in A draw lines vertically, intersecting lines drawn from A^1. Then a line traced through these several points of intersection, as shown by A^2, will constitute the profile of the horizontal return at the top and also the miter line as shown in elevation. If the normal profile were in the horizontal return at the foot of the pediment and the modified profile in the position of A^1, it would be immaterial whether the normal profile or a duplicate of the modified profile were in the place of A by which to obtain the intersecting lines, as the projection of the points only is to be considered in this operation, and that is the same in both cases.

For the pattern of the inclined molding proceed as follows: At right angles to the lines of the raking cornice lay off a stretchout of the profile of the raking cornice A^1, as shown by F G, through the points in which draw measuring lines in the usual manner. Place the T-square at right angles to the lines of the raking cornice, and, bringing the blade successively against the points in the profile A^2, which is the miter line in the elevation, cut the corresponding measuring lines, and through these points of intersection trace a line, as shown by G H. Then G H will be the pattern of the top end of the raking cornice to miter against the horizontal return. For the pattern of the horizontal return the usual method would be to construct an elevation of it in a manner similar to that described for the return at the foot of the gable in the preceding demonstrations; the equivalent of this, however, can be done in a way to save a considerable portion of the labor.

As the view of the miter line is the same in both the front and the side elevation the pattern may be developed from the front just obtained in the following manner, with the result, however, that the pattern will be reversed: Draw the line K M perpendicular to the

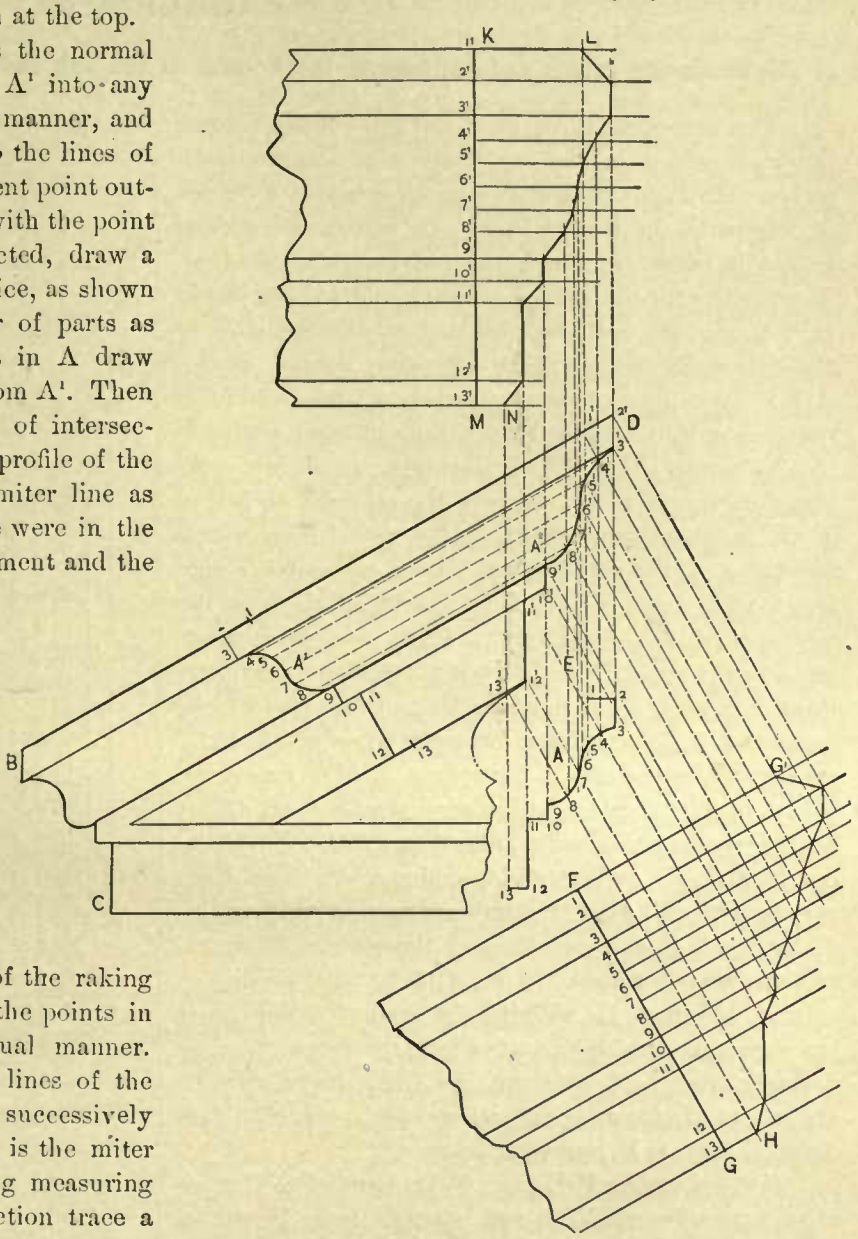


Fig. 392.—To Obtain the Profile of the Horizontal Return at the Top of a Broken Pediment Necessary to Miter with a Given Inclined Molding, and the Patterns of Both.

lines of the horizontal return, as it would be if shown in elevation. Upon K M lay off a stretchout of the profile A^2, all as shown by the small figures, and through the points draw the usual measuring lines. With the T-square parallel to the stretchout line K M

bring the blade successively against the points in the profile A^2, cutting the corresponding measuring lines. Through these points of intersection trace a line, as shown by N L, which will be the pattern of the end of the horizontal return to miter against the gable cornice, as shown.

PROBLEM 94.

To Obtain the Profile and Patterns of the Returns at the Top and Foot of a Segmental Broken Pediment.

The preceding three problems treat of the various miters involved in the construction of angular pediments. In Fig. 393 is shown an elevation of a curved or segmental broken pediment in which the normal profile is placed in the horizontal return at the foot. The profiles for the curved molding and for the return at the top can both be obtained at one operation in the following manner: Divide the normal profile A B C into any convenient number of parts, and from the points thus obtained draw lines at right angles to the horizontal line C F of elevation, as shown. At any convenient point draw G H, at right angles to A G, cutting them. With Q, the point from which the curve of the molding was struck, as center, strike arcs from the points in A B C, extending them in the direction of D indefinitely. From any convenient point in the arc A D, as L, draw a line to the center Q. From L draw L M, at right angles to L Q, upon which, beginning at L, set off the distances contained in H G, as shown by the small figures in L M. From the points of intersection where arcs struck from Q cut L Q draw lines at right angles to L Q. From the points in L M, and at right angles to it, drop lines cutting those of similar number drawn at right angles to L Q. A line traced through these points of intersection, as shown by M K, will be the profile of curved molding. It will be observed that the points for obtaining the profile are where the perpendiculars dropped from L M intersect the lines drawn at right angles to L Q, and not where the perpendiculars dropped from L M intersect the arcs.

For the profile D E draw N D, parallel to C J, or at right angles to N O, and, starting from D, set off on D N the same points as are in G H. Drop perpendiculars from these points to the arcs of similar numbers drawn from A B, when a line traced through the points of intersection will form the desired profile, as show by D E. The normal profile is also drawn above G H and N D at X and Z to show that the same result is obtained by using the points in G H to set off on L M and N D as would be obtained by dropping the points from the profiles. The patterns for the returns would be obtained as described in the previous problems.

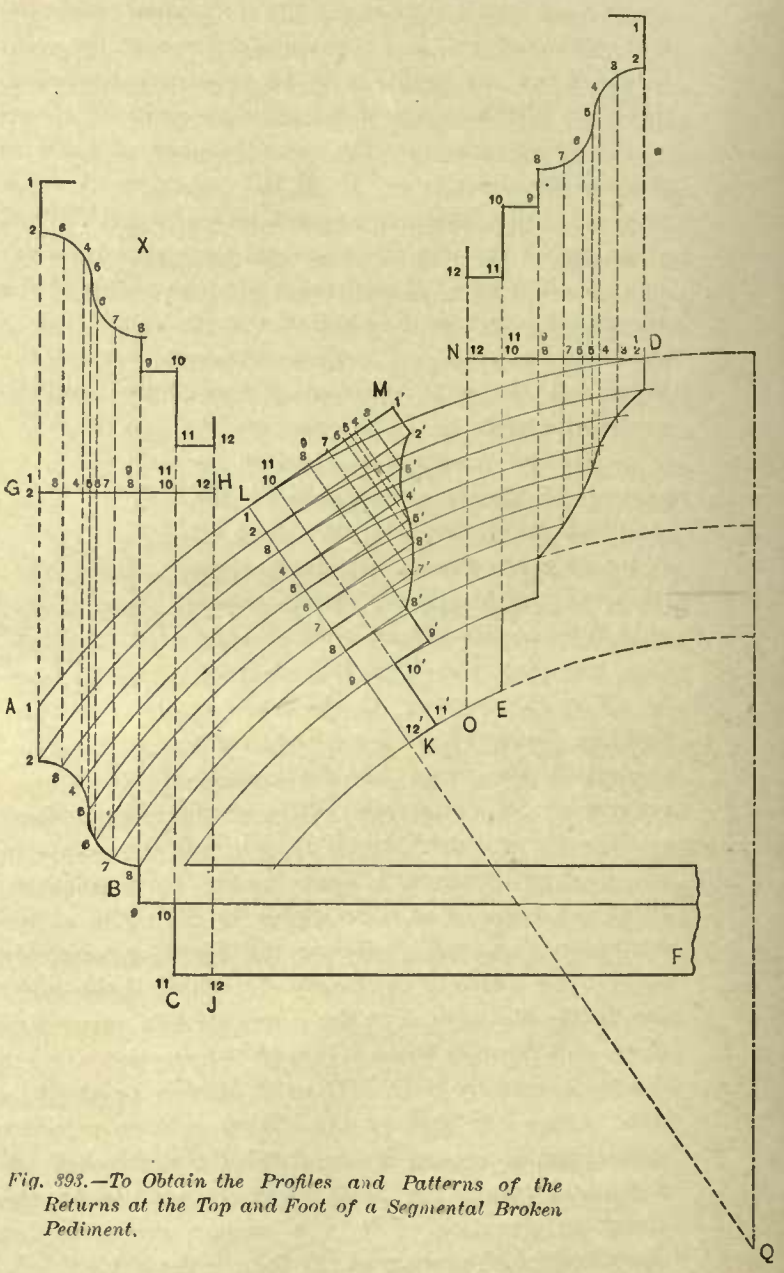


Fig. 393.—To Obtain the Profiles and Patterns of the Returns at the Top and Foot of a Segmental Broken Pediment.

Problems describing the method of obtaining the pattern for the blank for the curved molding will be found in Section 2 of this chapter.

PROBLEM 95.

From the Profile of a Given Horizontal Molding, to Obtain the Profile of an Inclined Molding Necessary to Miter with it at an Octagon Angle in Plan, and the Patterns for Both Arms of the Miter.

Another example wherein is required a change of profile in order to produce a miter between the parts is shown in Fig. 394. In this case the angle shown in plan between the abutting members is that of an octagon, as indicated by B C D. To produce the modified profile and to describe the patterns proceed as follows: In the side B C draw the normal profile A, as indicated, and in the corresponding side, as shown in elevation by N O L K, draw a duplicate profile, as shown by A'. Divide both of these profiles into the same number of parts, and from the points in each carry lines parallel to the lines of molding in the respective views, producing the lines drawn from profile A until they meet the miter line C X. From the points thus obtained in C X erect lines vertically until they meet those drawn from profile A', intersecting as shown from O to L. Through these points of intersection draw the line O L, which will be the miter line in elevation corresponding to C X of the plan. From the points in O L carry lines parallel with the raking molding in the direction of P indefinitely. At any convenient point outside of the raking cornice draw a duplicate of the normal profile, as shown by A^2, placing its vertical line at right angles to the lines of the raking cornice. Divide the profile A^2 into the same number of spaces as employed in A and A', and from these points carry lines at right angles to the lines of the raking cornice, intersecting those of corresponding number drawn from the points in O L. Trace a line through these intersections, as shown from R to S. Then R S will be the required profile of a raking cornice to miter against a level cornice of the profile A at an angle indicated by B C D in the plan, or an octagon angle.

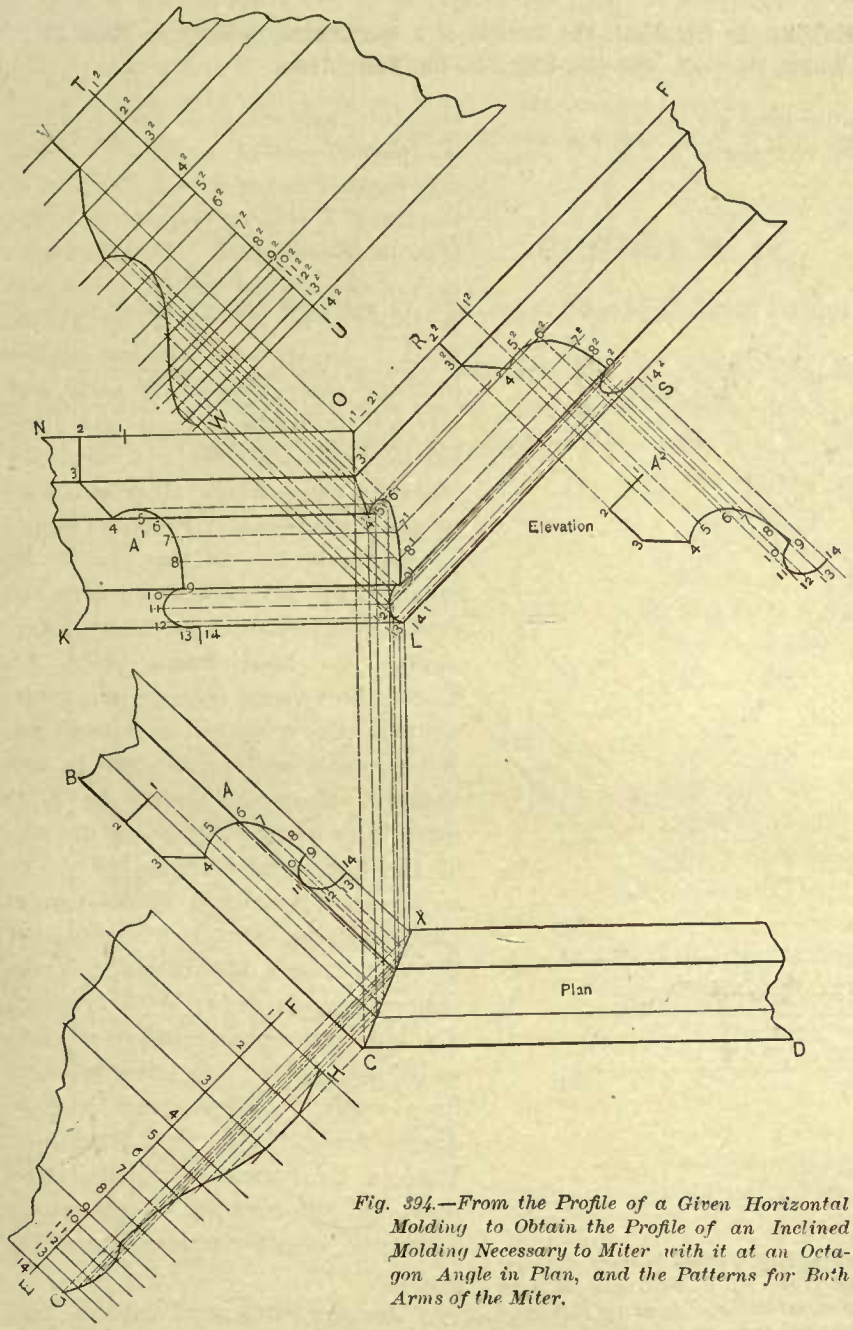


Fig. 394.—From the Profile of a Given Horizontal Molding to Obtain the Profile of an Inclined Molding Necessary to Miter with it at an Octagon Angle in Plan, and the Patterns for Both Arms of the Miter.

For the pattern of the level cornice, at right angles to the arm B C in the plan lay off a stretchout of the profile A, as shown by E F, through the points in which draw the usual measuring line. With the T-square at right angles to B C, bringing the blade successively against the several points in X C, cut corresponding measuring lines drawn through E F. Then a line traced through these points, as shown from H to G, will be the required pattern of the horizontal cornice. In like manner, for the pattern of

the raking cornice, at right angles to its lines lay off a stretchout of the profile R S, as shown by U T, through the points in which draw measuring lines in the usual manner. With the T-square at right angles to the lines of the raking cornice, and brought successively against the points in the miter line O L, as shown in elevation, cut the corresponding measuring lines. Then a line traced through the points thus obtained, as shown by W V, will be the required pattern for the raking cornice.

PROBLEM 96.

From the Profile of a Given Inclined Molding, to Establish the Profile of a Horizontal Molding to Miter with it at an Octagon Angle in Plan, and the Patterns for Both Arms.

In Fig. 395, let B C D be the angle in plan at which the two moldings are to join, U O V the angle in elevation, and A or A' the normal profile of the raking mold. To form a miter between moldings meeting under these conditions a change of profile is required. To obtain the modified profile for the horizontal arm and the miter line in elevation proceed as follows: Draw the normal profile A with its vertical side parallel to the lines in the plan of the arm E X D C, corresponding to the front of the elevation. Draw a duplicate of the normal profile in correct position in the elevation, as shown by A'. Divide both of these profiles into the same number of parts, and through the points in each draw lines parallel with the plan and with the elevation respectively, all as indicated by the dotted lines. From the points in the miter line of the plan C E, obtained by the lines drawn from the profile A, carry lines vertically, intersecting the lines drawn from A'. Then a line traced through the intersections thus obtained, as shown from N to O, will be the miter line in elevation. From the points in N O carry lines horizontally along the arm of the horizontal molding N O U Y, as shown. At any convenient point outside of this arm, either above or below it, draw a duplicate of the normal profile, as shown by A², which divide into the same number of parts as before, and from the points carry lines vertically intersecting the lines drawn from N O, just described Then a line traced through these points of intersection, as shown by T S, will give the required modified profile.

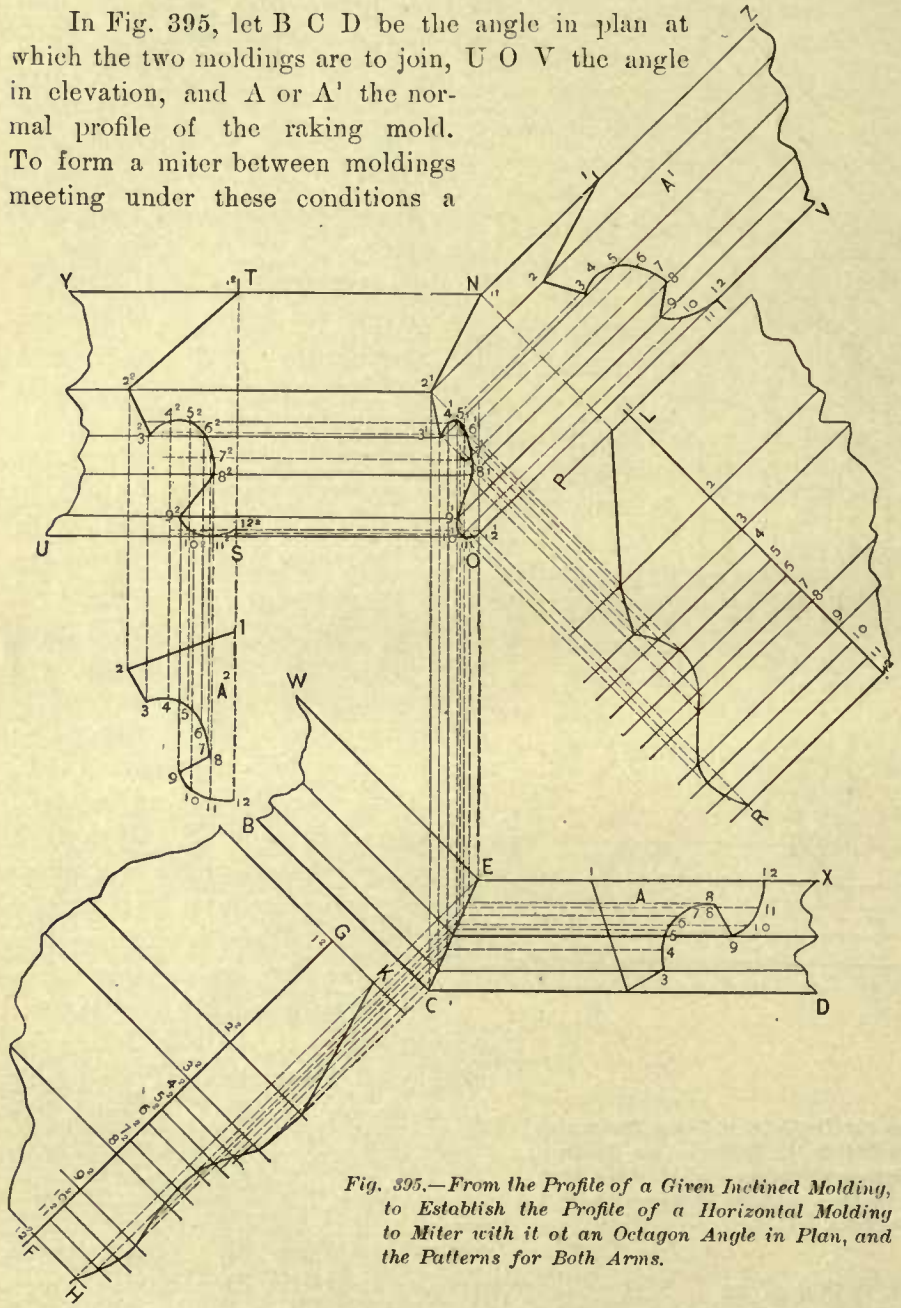


Fig. 395.—From the Profile of a Given Inclined Molding, to Establish the Profile of a Horizontal Molding to Miter with it ot an Octagon Angle in Plan, and the Patterns for Both Arms.

For the patterns of the arm Y N O U proceed as follows: At right angles to the same, as shown in plan by W E C B, lay off on any straight line, as G F, a stretchout of the profile T S, all as shown by the small

figures 1^2, 2^2, 3^2, etc. Through these points draw measuring lines in the usual manner. With the T-square parallel to the stretchout line, and brought against the points of the miter line E C in plan, cut corresponding measuring lines, as indicated by the dotted lines, and through these points of intersection trace a line, as shown by K H. Then K H will be the shape of the end of Y N O U to miter against the raking molding.

It will be easily understood that the points as found upon the line E C are just the same as would be obtained there if the newly obtained profile were drawn into the plan of the arm C B W E and the points were dropped from it to the line E C according to the rule. For the pattern of the raking molding, at right angles to the arm N Z V O in the elevation lay out a stretchout, L M, from the profile A^1. Through the points in this stretchout draw measuring lines in the usual manner. Place the T-square parallel to the stretchout line, and, bringing it against the several points in the miter line in elevation N O, cut corresponding measuring lines, as indicated by the dotted lines. Then a line traced through these points of intersection, as shown by P R, will be the shape of the cut on the arm N Z V O to miter against the horizontal molding.

PROBLEM 97.

The Miter Between the Moldings of Adjacent Gables of Different Pitches upon a Pinnacle with Rectangular Shaft.

The problem presented in Figs. 396 and 397 is one occasionally arising in pinnacle work. The figures represent the side and end elevations of a pinnacle which

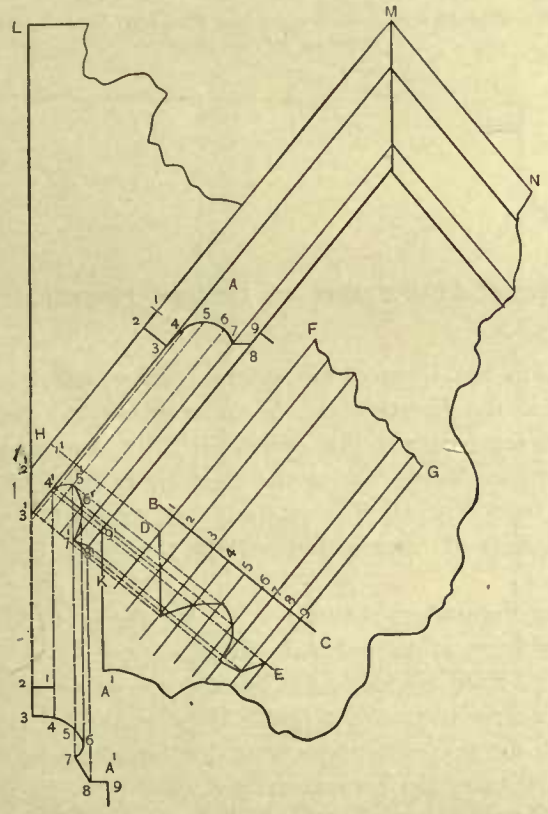


Fig. 396.—Side Elevation of Rectangular Pinnacle, Showing the Miter Between the Moldings of Adjacent Gables.

is rectangular, but not square. All of its faces are finished with gables whose moldings miter with each other at the corners, and which are of the same hight in the line of their ridges, as indicated by L M and L^1 M^1. Whatever profile is given to the molding in one face of such a structure, the profile of the gable in the adjacent face will require some modification in order to form a miter. In Fig. 396 let A be the normal profile of the molding placed in the gable of the side elevation. Before the miter patterns can be developed it will first be necessary to obtain the miter line or joint between the moldings of the adjacent gables as it will appear in the elevation, to accomplish which proceed as follows: Draw a duplicate of A, placing it in a vertical position directly below or above the point at which the two moldings are to meet, as shown by A^1. Divide both of these profiles into the same number of parts, as indicated by the small figures, and through these points draw lines intersecting in the points from H to K, as shown. Then a line traced through these intersections will be the miter line in elevation. For the pattern of the molding of the side gable lay off at right angles to H M a stretchout of the profile A, as shown by B C, through the points of which draw the usual measuring lines. Place the T-square at right angles to the lines of the molding, or, what is the same, parallel to the stretchout line, and, bringing it against the several points in the miter line H K, cut corresponding measuring lines. Then a line traced through these points, as shown by D E, will be the shape of the cut at the foot of the side gable to miter against the adjacent gable.

The next step is to obtain the correct profile of the molding on the adjacent gable. H K having been established as the correct elevation of the miter, its

outline may now be transferred, with its points, to the end elevation of the pinnacle, as shown at H' K', Fig. 397, reversing it, because it appears here at the right side of the gable, whereas it appeared at the left of the other. Draw a duplicate of the normal profile, as shown at A^2, placing its vertical lines at right angles to the lines of the gable, and divide it into the same spaces as in the first operation. From these points draw lines at right angles across the molding, which intersect with lines drawn parallel to the molding from the points in the miter line H' K'. Then a line traced through these points of intersection will form the required modified profile, as shown by W X.

For the pattern of the molding of the end gable proceed as follows: At right angles to the lines of the raking cornice lay off a stretchout of the profile W X, as shown by P R, through the points in which draw measuring lines in the usual manner. With the T-square at right angles to the lines of the raking cornice, bringing it successively against the points in K' H', cut corresponding measuring lines. Then a line traced through these points of intersection, as shown from S to T, will be the pattern required.

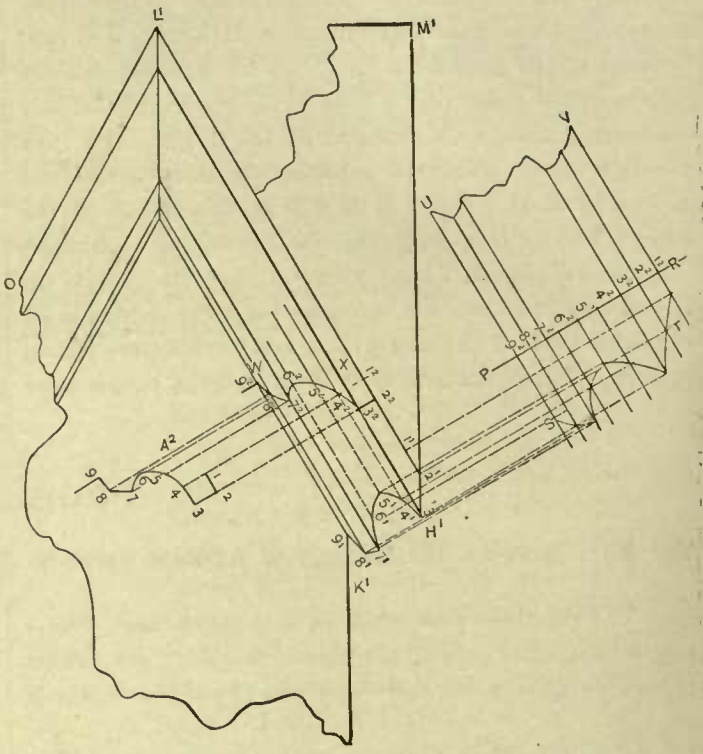


Fig. 397.—End Elevation of Rectangular Pinnacle, Showing Same Miter as in Fig. 396.

PROBLEM 98.

The Miter Between the Moldings of Adjacent Gables of Different Pitches upon an Octagon Pinnacle.

This problem differs from the preceding one in that the angle of the plan is octagonal instead of square, but like it requires a change of profile in one of the gables in order to effect a miter. In Figs. 398 and 399 are shown a quarter plan of pinnacle and the elevations of two adjacent gables of different widths but of similar hights. Let A' B' F' O G' D' of Fig. 398 be a correct elevation and A B C G be a quarter plan of the structure. In that portion of the plan corresponding to the part of the elevation shown to the front draw the normal profile E, placing its vertical side parallel to the lines of the plan. Divide it into any convenient number of spaces, and through these points draw lines parallel to the lines of the plan, cutting C O', the miter line in plan, as shown. In like manner place a duplicate of the normal profile, as shown by E' in the elevation. Divide it into the same number of equal parts, and through the points draw lines parallel to the lines of the raking cornice, which produce in the direction of N O indefinitely. Bring the T-square against the points in C O', and with it erect vertical lines, cutting the lines drawn from E', as shown from N to O. Then a line, N O, traced through these points of intersection will be the miter line in elevation.

For the pattern of the miter at the foot of the wide gable or gable shown in elevation proceed as follows: At right angles to the lines of the gable cornice lay off a stretchout of the profile E', as shown by H K, through the points in which draw the usual measuring lines. Placing the T-square at right angles to the lines of the cornice, or, what is the same, parallel to the stretchout line, and bringing it against the several points in N O, cut corresponding measuring lines. Then a line traced through the points of intersection thus obtained, as shown from L to M, will be the pat-

tern of the miter at the foot of the gable shown in elevation. For the modified profile of the gable molding

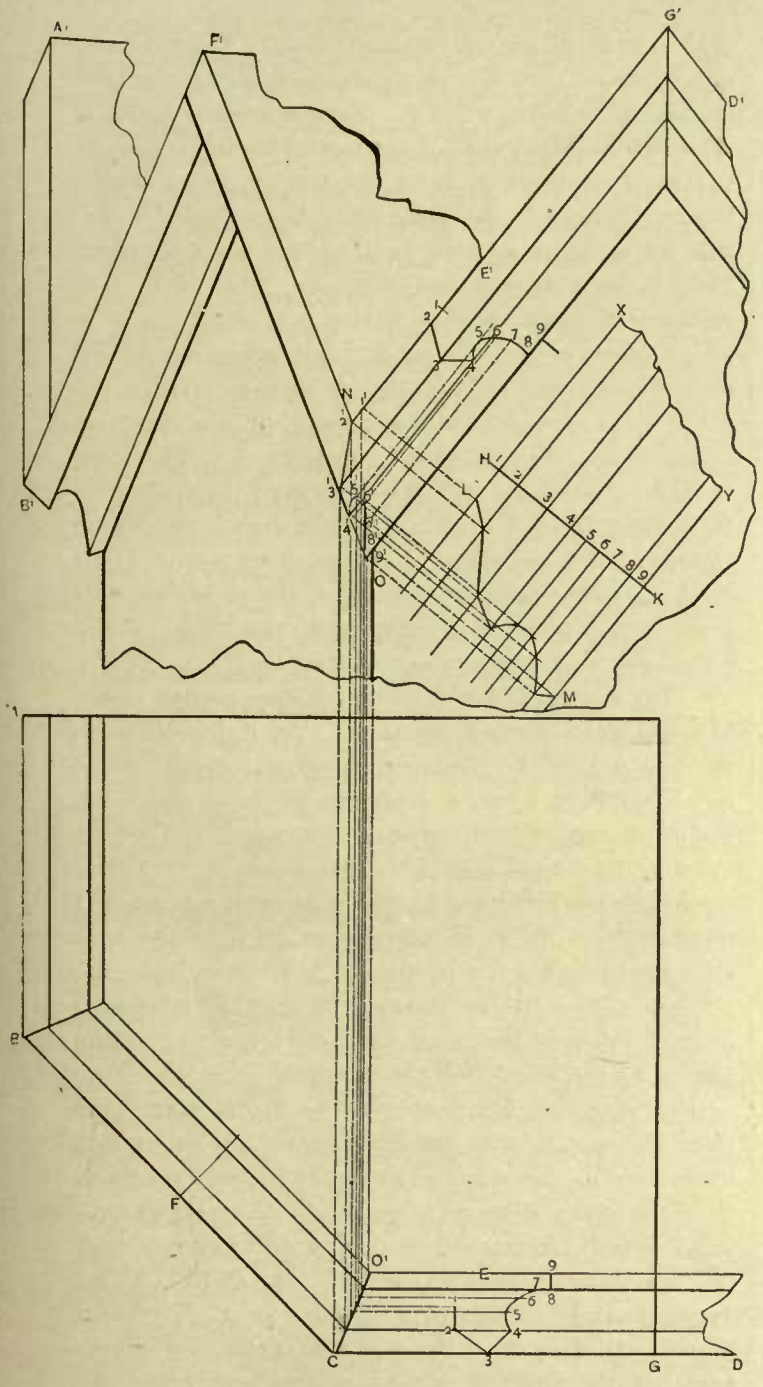


Fig. 398.—Quarter Plan and Elevation of Octagon Pinnacle, Showing Miter Between Moldings of Adjacent Gables of Different Pitches.

upon the narrow side proceed as follows: Draw a correct elevation of the narrow side, reproducing therein the miter line N O from Fig. 398 (reversing the same), as shown by R P in Fig. 399, and through the points, also reproduced from N O, carry lines parallel to the lines of the gable cornice indefinitely, as shown. Draw a duplicate of the normal profile at any convenient point outside of the gable cornice, as shown by E^2, placing its vertical side at right angles to A^2 R, or the lines of the cornice. Divide E^2 into the same number of parts as used in the other profiles, and through the points draw lines at right angles to the lines of the cornice, intersecting the lines drawn from P R. Through

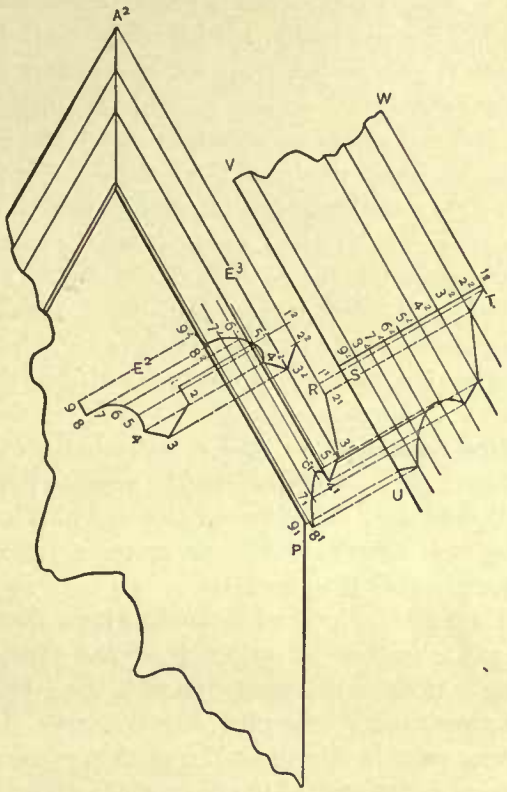


Fig. 399.—Elevation of Narrow Side of Octagon Pinnacle, Showing Same Miter as in Fig. 398.

these points trace a line, as indicated by E^3, which will be the modified profile.

To lay out the pattern take the stretchout of E^3 and lay it off on any straight line drawn at right angles to the lines of the cornice, as S T, and through the points in it draw the usual measuring lines. Place the T-square at right angles to the lines of the gable cornice, and, bringing it against the points in P R, cut the measuring lines, as indicated by the dotted lines. Then a line traced through these points of intersection, as shown by U T, will be the pattern for the molding at the foot of the gable on narrow side.

PROBLEM 99.

The Patterns for a Cold Air Box in which the Inclined Portion Joins the Level Portion Obliquely in Plan.

The conditions of the problem are clearly shown in the plan and side elevation of Fig. 400, in which Z B C is the elevation and X C′ D′ Y is the plan of the level portion of a cold air passage joining a furnace just above the floor line. The inclined portion of the air passage or box is required to join the level portion at the angle Z A E of the side elevation, and at the angle Y A′ E′ when viewed in plan. These conditions are in many respects similar to those given in Problem 95, with the difference, however, that in this case the joint or miter between the level and the inclined portions does not appear as a straight line in the plan. It may be here remarked that the solution of this problem is more a matter of drawing than of pattern cutting, as nothing can be more simple than the cutting of a miter between two pieces of rectangular pipe when the required angle between them is known. This problem is capable of two solutions, both of which will be given, leaving the reader to choose which is the more adaptable to his requirements.

First Solution.—As above intimated, before the pattern can be developed it will be necessary to make careful drawings, in the preparation of which a knowledge of the principles of orthographic projection is necessary. (See Chapter III).

To proceed, then, with the drawings, first draw a plan and elevation of as much of the furnace as is necessary to show its connection with the cold air box, placing each part of the plan directly under its corresponding part in the elevation, so that as soon as any new point is determined in either of the views its position can be located in the other by means of a perpendicular line dropped from one view to the other. Upon the plan set off the width of the box *b* and draw parallel lines from the side of the furnace body to the right indefinitely, and upon the elevation set off its hight, *a*, from the floor line up, and draw A Z. A vertical line from the point X of the plan will give the point Z upon the elevation, or, in other words, show how far the curve of the furnace body cuts into the top and bottom surfaces of the cold air box. Next, upon the elevation locate the point A the required distance from the side of the body according to specification and find its position in the plan by means of a vertical line, as shown. From the point A in both views lines must be drawn to represent the angle or deflection of the pipe as it would appear in those views. Thus the elevation would show the slant, which is determined by the two dimensions *c* and *d*. Therefore from the point A of the elevation erect a perpendicular line equal to the required hight *c*, from the top of which draw a horizontal line to the right of a length equal to the amount of slant *d*, thus locating the point E, which connect by a straight line with A. Then will A E represent the angle of the inclined portion of the pipe as it appears in the elevation. But according to the requirements the pipe is also to have an offset a distance equal to *e*—that is, the point E of the elevation is nearer the observer than the point A. Therefore from A′ of the plan draw a line forward the amount of the offset, from the end of which draw a line to the right, in length equal to *d*, or in other words till it comes directly under the point E of the elevation, thus locating that point in the plan, and draw A′ E′, which will show the apparent angle in the plan.

The depth and width of the oblique portion of the box will next demand attention. At right angles to the line A E of the elevation set off the depth of the box *a* and draw a line to represent the lower near corner of the box, which continue downward until it cuts the floor line, as shown at D; then draw A D, which represents the miter cut for the side of the box. At right angles to A′ E′ of the plan set off the width *b*, as shown, and draw a line parallel to A′ E′ intersecting the line from X at B′, as shown, and draw A′ B′, which gives the plan of the miter cut across the top of the box. As the point D of the elevation is in the same vertical plane as A it may now be dropped into the plan, intersecting with the line showing the front side of the box in that view, as shown at D′; and the point B′ of the plan, being on a level with A′, may be projected into the elevation, where it would intersect with the line showing the top of the box at B. A line drawn from D′ of the plan parallel to A′ E′ (shown dotted) will then show the position of the lower near angle of the inclined portion of the box, and a line from B of the elevation parallel to A E will show the position in that view of the further top corner of the box.

The position in the two views of the remaining angle of the inclined portion of the box may be ascertained in several ways: The width *b* may be set off

from D′ of the plan and a line drawn which will intersect with X B′ continued, as shown at C′; thence it may be projected into the elevation at C, as shown; or the width *a* may be set off from B of the elevation, thus locating the line which intersects with the floor at C, which point may be dropped into the plan, thus locating the point C′; or, again, B C may be drawn parallel to A D, or D′ C′ may be drawn parallel to A′ B′, all producing the same result.

In the case in Problem 95, above referred to, it was noted that if the normal profile is adhered to in the level arm, the profile of the gable mold must be changed or "raked" before a perfect miter joint can be obtained. What is true in the case of the gable miter is equally true in the case of the furnace pipe—a correct profile or cross section of the box must be developed in order that a correct stretchout may be obtained for use in cutting the miter of the inclined arm of the pipe. As neither the plan nor the elevation, which have been correctly obtained, gives the true length of the inclined piece—that is, the true distance from A to E—it will be necessary to obtain still another elevation, in which such distance is correctly shown. As A′ E′ of the plan gives the horizontal distance between the points A and E, and *c* represents the vertical distance between them, if a right angled triangle be constructed with A′ E′ as a base and the hight *c* as the perpendicular, its hypothenuse will then give the desired measurement. Such a triangle properly forms part of an oblique elevation which may be projected from the plan in the following manner: Parallel to A′ E′, at any convenient distance away, draw a line to represent the level of the floor, as shown; above which, at a distance equal to *a*, draw another parallel line, X^2 A^2, representing the hight of the horizontal arm of the pipe. Above the line X^2 A^2, at a hight equal to *c*, draw still another line, upon which the point E is subsequently to be located.

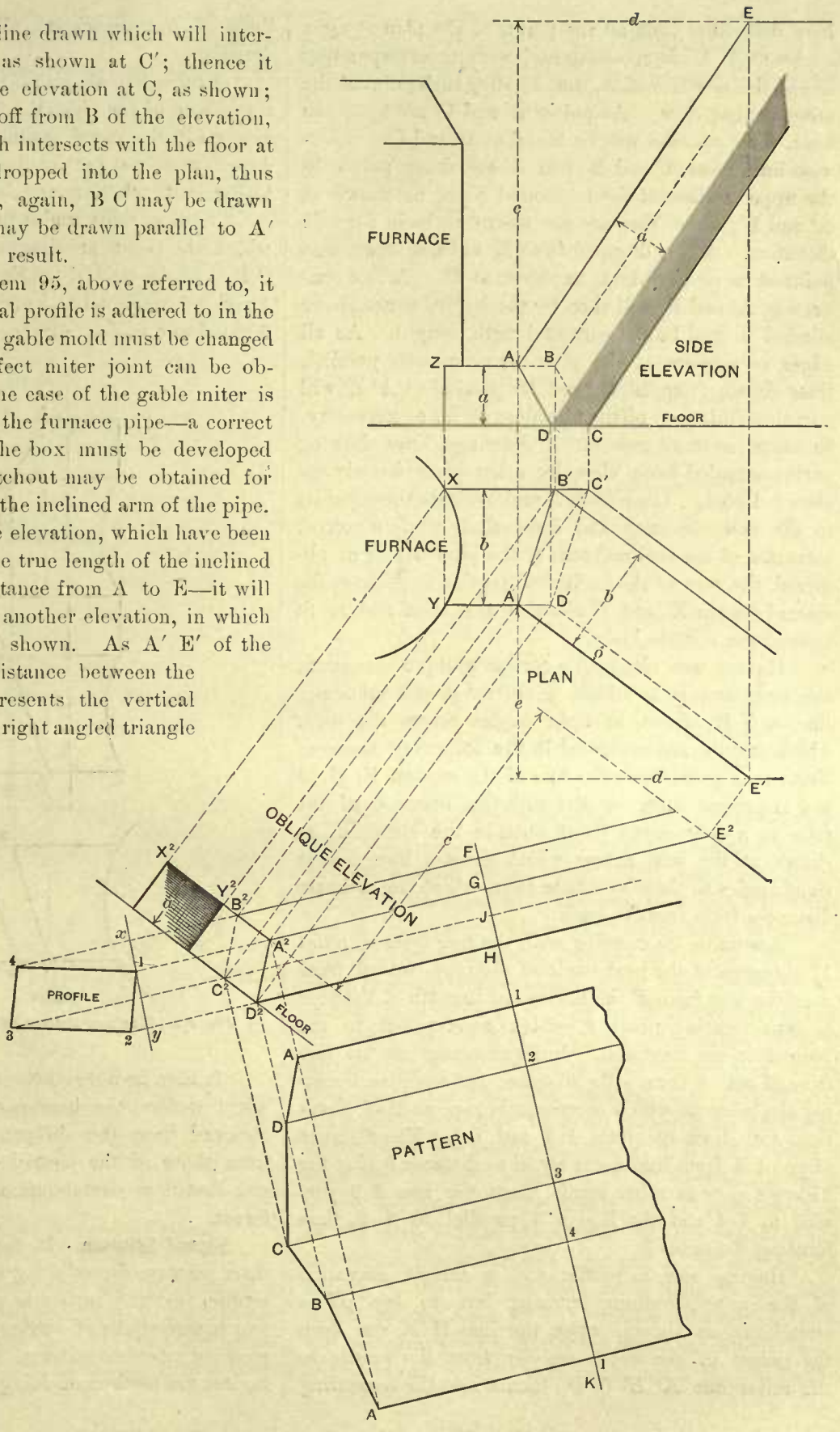


Fig. 400.—Plan and Elevations of a Cold Air Box in Which the Inclined Portion Joins the Level Portion Obliquely in Plan.—First Solution.

Now drop lines from all the points of the plan at right angles to A′ E′, intersecting each with its corresponding line of the new elevation, thus locating each point of the miter in that view As points D′ and C′ are upon the floor, their position will be found at D^2 and C^2. Likewise lines from A′ and B′ will locate those points in the upper surface of the horizontal pipe, as shown at A^2 and B^2, where they are also shown to be in the side elevation. A line dropped from E′ will also locate that point at its proper hight, as shown at E^2. A line connecting A^2 and E^2 will then be the hypothenuse above alluded to and be the correct length sought. As all edges or corners of the pipe are necessarily parallel, lines drawn from B^2 C^2 and D^2 parallel to A^2 E^2 will complete this part of the elevation as far as necessary. In these, as in all geometrical drawings, lines showing parts concealed from view by other parts are always shown dotted. Lines from X and Y locate those points in the new elevation and show that, while a correct elevation of the inclined arm of the pipe has been obtained, the view of the horizontal portion is oblique, the space between X^2 and Y^2 showing the open end to fit against the furnace body.

Having now obtained a correct oblique elevation, the next step is to obtain a correct profile upon any line, as F H, drawn at right angles across the pipe, which may be accomplished in the following manner: From each point upon the line of the section F, G, J and H project lines parallel with the direction of the pipe to a convenient point outside the elevation, as shown at the left, across which draw a line, *x y*, at right angles to them as a base from which to measure distances from front to back.

Assuming its crossing with the line from G (point 1) to represent the near angle of the pipe, set off from *x* on the line from F the horizontal breadth of the pipe *b*, thus locating point 4, which corresponds to the point F in the elevation. In like manner on the line from H set off from *y* the distance *o* of the plan, locating the point 2, which corresponds to point H of elevation, and draw the lines 1 4 and 1 2. The distance of point 3 from line *x y* is equal to distance *b* plus the distance *o*, or in other words, draw the line 2 3 parallel to 1 4 and the line 4 3 parallel to 1 2, thus locating the point 3.

Having now a profile and a correct elevation of the miter, nothing remains but to lay off a stretchout, as shown, upon the line H K and drop the points in the usual manner from the profile to the miter line A^2 B^2 C^2 D^2, thence into the measuring lines of the stretchout, all as clearly shown in the drawing.

As the plan shows all the dimensions of the horizontal arm of the pipe, the pattern for that can be developed in the usual manner. To avoid confusion a duplicate of that part of the plan has been transferred to Fig. 401, where a stretchout of the normal profile is laid off at right angles to the lines of the pipe, into which the points are dropped from the miter line A B C D. In the normal profile of course the distances 1 4 and 2 3 are equal to *b* and the distances 1 2 and 4 3 equal to *a* of Fig. 400.

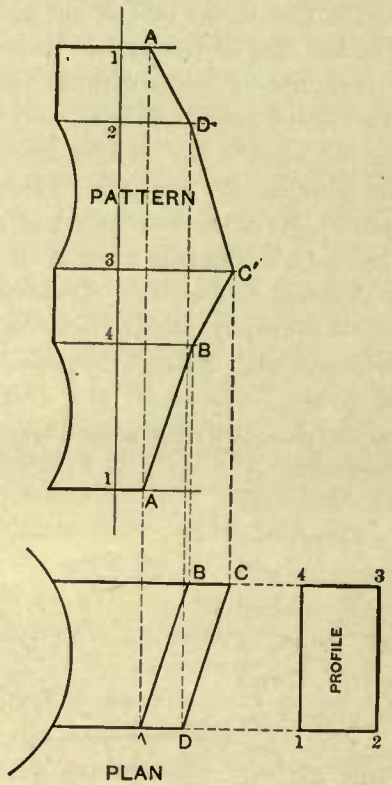


Fig. 401.—Plan and Pattern of Level Arm of Cold Air Box.

It may be noted here that, as is the case in all raked profiles, the dimensions and shape of the profile obtained from the oblique elevation differ somewhat from those of the normal profile shown in Fig. 401, and that their stretchouts are therefore necessarily different.

Second Solution.—It may be asked naturally, is there no way of producing a miter without a change of profile, just as a carpenter would saw off the ends of two square sticks of timber of the same section and produce a perfect miter at an oblique angle? There is, but the method of doing it is not so apparent as the

one just described. To accomplish this a drawing or view must be obtained, in which the surface of the paper represents a plane common to both arms of the pipe. As three points determine the position of a plane, it will be seen at once that such a plane passes through the points Z, A and E of the side elevation, Fig. 400. The best means of obtaining this view is shown in Fig. 402, in which the plan shown in Fig. 400 has been reproduced, but turned around in such a manner as to facilitate the projection from it of an end

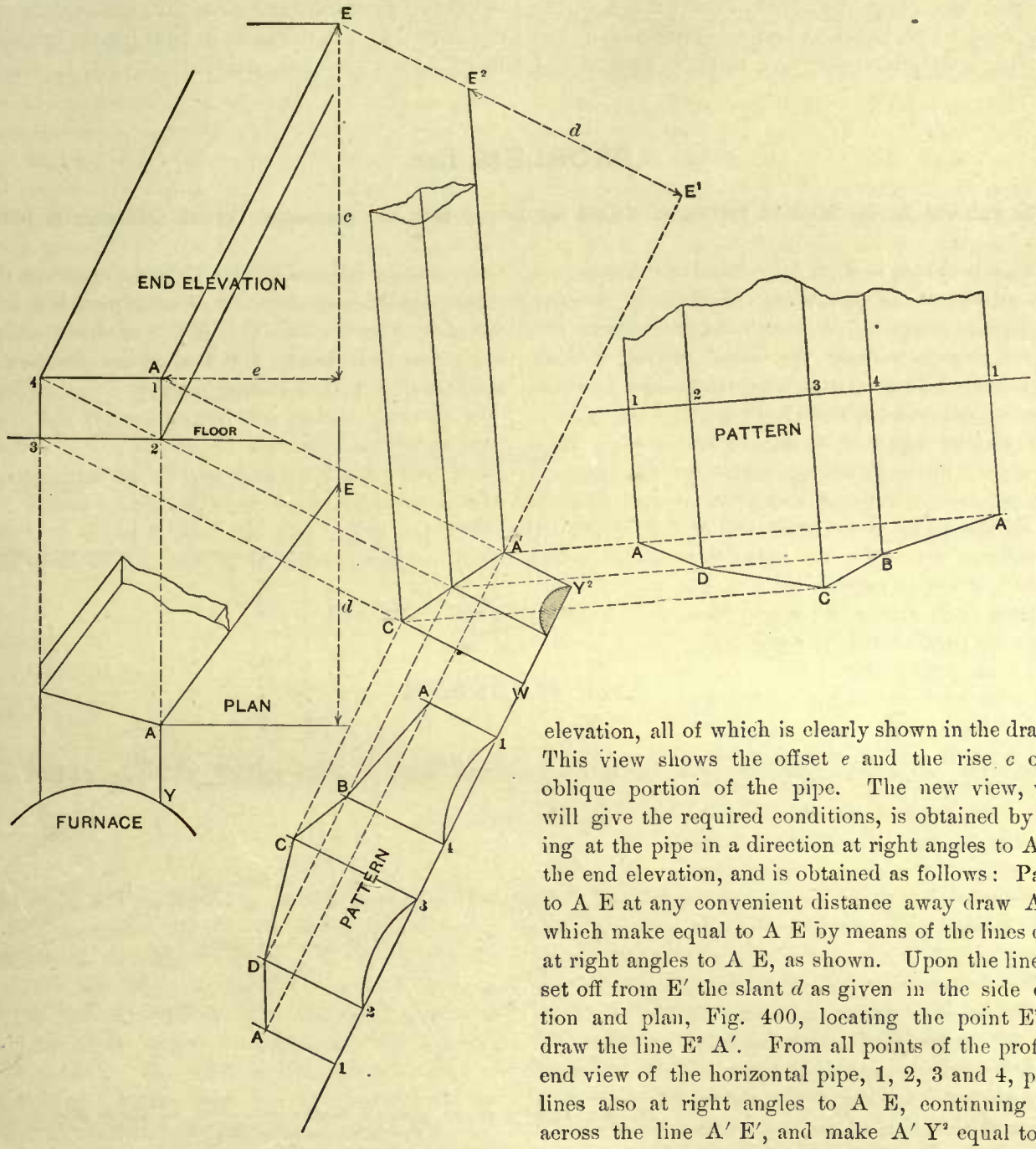


Fig. 402.—Patterns of Cold Air Box.—Second Solution.

elevation, all of which is clearly shown in the drawing. This view shows the offset *e* and the rise *c* of the oblique portion of the pipe. The new view, which will give the required conditions, is obtained by looking at the pipe in a direction at right angles to A E of the end elevation, and is obtained as follows: Parallel to A E at any convenient distance away draw A′ E′, which make equal to A E by means of the lines drawn at right angles to A E, as shown. Upon the line E′ E set off from E′ the slant *d* as given in the side elevation and plan, Fig. 400, locating the point E^2, and draw the line E^2 A′. From all points of the profile or end view of the horizontal pipe, 1, 2, 3 and 4, project lines also at right angles to A E, continuing them across the line A′ E′, and make A′ Y^2 equal to A Y of the plan. Then A′ Y^2 will be the length of the horizontal arm in the new view and A′ E^2 will be the length of the inclined arm, both lying in the same plane, and the angle E^2 A′ Y^2 will be the angle at which the two arms meet. Under the above conditions, then, a line which bisects that angle, as A′ C, will be the

miter line between the two arms. As the two arms of the miter are symmetrical, the view can be completed, if desired, by drawing lines parallel with A′ E² from the points of intersection with the lines from the end view with the miter line A′ C. As 1 2 3 4 is the profile from which the short arm was projected in the new view, a stretchout may now be taken from it and laid off on any line at right angles to C W and the points dropped in the usual manner, all as shown. If desired, the stretchout may also be laid off at right angles to the inclined arm and the pattern for this piece thus developed from the same miter line, although the miter cut A B C D A is the same in both pieces, one simply being the reverse of the other.

PROBLEM 100.

The Patterns for the Inclined Portion of a Cold Air Box to Meet the Horizontal Portion Obliquely in Plan.

This problem is here introduced on account of the similarity of its conditions with those of the one immediately preceding, although, as its patterns are obtained entirely without the use of profiles, it does not properly belong in this connection. Its solution will serve to show what widely different means may be employed to obtain the same ends. In the preceding case the miter cut was obtained without reference to the miter at the upper end of the oblique arm. In this case the oblique portion is required to join, at its upper end, with another arm like and exactly parallel with the arm joining its lower termination.

Under such conditions it follows that the planes of the upper and lower miters must be parallel, and, therefore, that miter cut at the upper end of either of the faces of the oblique portion must be parallel with that at the lower end of the same. Advantage may be taken of these conditions to obtain a very simple solution of the problem, as will be seen below.

The first requisite is, of course, a correctly drawn elevation and plan in which all the points in each are duly projected from corresponding points in the other view. In Fig. 403 is shown a plan and elevation of the box, with the lines of projection connecting corresponding points in each, all of which may be constructed very much as described in the preceding problem. The inclined arm is required to have a rise equal to *a* of the elevation and a forward projection equal to *b* of the plan. Corresponding points in the two views are lettered alike. Thus the elevation shows clearly that it is an elevation of the front A B F E of the plan, with the back C D H G dotted behind, while the plan shows clearly A B D C of the elevation with the bottom E F H G dotted below.

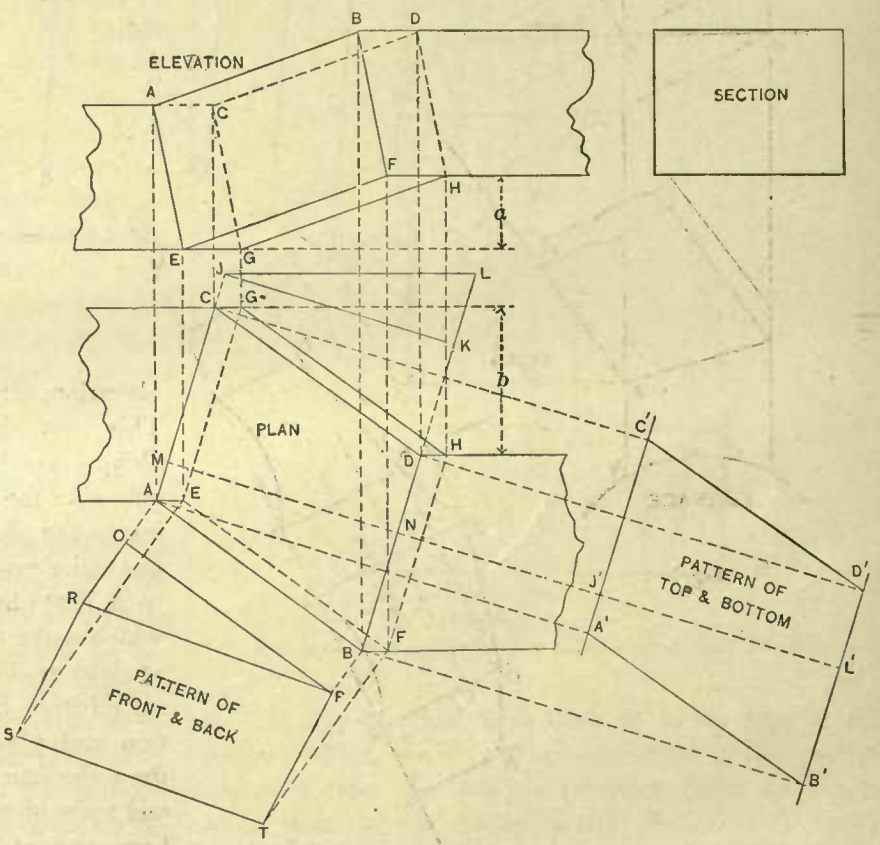


Fig. 403.—Patterns for the Inclined Portion of a Cold Air Box to Meet the Level Portion Obliquely in Plan.

The first important information to be derived from the correctly drawn views is that the front and back are the same, likewise the top and bottom are alike. The patterns of the top and front are given separately, upon the supposition that joints will be made at all of

the angles; should they be wanted in one piece they could readily be connected. As all the surfaces of the inclined portion of the pipe are oblique to the given view, only some of their dimensions will be correct as they appear on the paper. An inspection of both elevation and plan will show that the lines A C and B D are both horizontal and parallel, and, therefore, correct as they appear in the plan, and may be used as given in the construction of a pattern of the top piece. The shortest distance between these two lines will be represented by a line at right angles to both, as M N. Since the point N in the line B D is higher than the point M of the line A C, by the distance *a* of the elevation, it will be necessary to construct the diagram J L K in order to get the correct distance between the points M and N. J K is made equal to the distance M N, as indicated by the dotted lines. K L is equal to the rise given in the elevation; hence the distance J L represents the true distance between the points M and N. Upon the continuation of the line M N of the plan set off the distance J L, as shown at J′ L′. Through each of these points lines are drawn parallel to A C and B D of the plan. The line A′ C′ is made equal to A C, and B′ D′ is made equal to B D by means of the dotted lines drawn parallel to M N. This pattern is completed by connecting the point A′ with B′ and C′ with D′.

In developing the pattern of the side A B F E the same course might be pursued, beginning with the lines A E and B F, whose lengths are correctly given in the elevation, but for the sake of diversity another method has been employed. Beginning with the known fact that the point B is higher than the point A, as shown by *a* in the elevation, construct a diagram, O P R, making O P equal to and parallel with A B of the plan, and O R equal to *a*, thus giving R P as the correct length of the line represented by A B of the plan. From the points E and F draw, at right angles to E F, the lines E S and F T indefinitely. Since the distances A E and B F are the same and are correctly given in the elevation, take that distance between the feet of the dividers, and placing one foot at the point R describe a small arc, cutting the line E S in the point S. By repeating this operation from the point P, the point T is established in the line F and T. Lines connecting the points R S, S T and T P will complete the pattern of the front and back.

PROBLEM 101.

The Pattern of a Hip Molding upon a Right Angle in a Mansard Roof, Mitering Against the Planceer of a Deck Cornice.

Let Z X Y V in Fig. 404 be the elevation of a deck cornice, against the planceer of which a hip molding, shown in elevation by U W Y T, is required to miter. Let the angle of the roof be a right angle, as shown by the plan Q D A′, Fig. 405, D N representing the plan of the angle over which the hip molding is to be placed. This angle is also shown by B A of the elevation. As the only view which will show the correct angle at which the hip molding meets the planceer is a view at right angles to the line D N, the first step in the development of the patterns will be to construct such a diagonal elevation. Assume any point, as A, in the elevation on any line representing a plain surface in the profile of the roof, as B A. Through A draw a horizontal line indefinitely, as shown by L A C. From B, the point in which the line A B meets the planceer, drop a vertical line, cutting the horizontal line drawn through A at the point C, all as shown by B C. Produce the line of planceer W Y, as shown by W′ Y′. Draw a duplicate of the plan, Q D A′ in Fig. 405, in such a manner that the diagonal line D N shall lie parallel to the horizontal line drawn through A, all as shown by Q′ D′ A². At right angles to the line D′ A², at any convenient point, as A², draw the line A² C′, in length equal to the distance A C in elevation, and through C′ draw a line parallel to D′ A², as shown by I N′, cutting the diagonal line D′ N′ in the point N′. Then D′ N′ represents the diagonal plan of that part of the hip from B to A in the elevation. From N′ erect a perpendicular, N′ M, which produce until it

meets the line carried horizontally from the planeeer in the point B'. In like manner from D' erect a perpendicular, which produce until it meets the horizontal line L C in the point L. Connect L and B', as shown, which will constitute the desired oblique projection of A B.

The next step will be to construct a section of the hip molding upon a line at right angles with it, as G H, assumed at any convenient point. It might be supposed that in such a section the two fascias of the hip molding would be at right angles to each other, as they undoubtedly would appear in the plan Q D A' of Fig. 405 or in a section on any horizontal line, as L M. The object of this part of the demonstration is to show exactly what that angle would be and how to obtain it.

Assume any point in the diagonal plan, as E, in the side D' A', from which erect a line perpendicular to D' N', as shown by E F, which produce until it meets the horizontal line L C in the point L', and thence carry it upward parallel to L B', cutting G H in the point F'. On either side of F' lay off a space equal to F E of the diagonal plan, as shown by F' E' and F' E'. Through these points E' and E' draw lines to K, the intersection of the lines L B' and G H. From

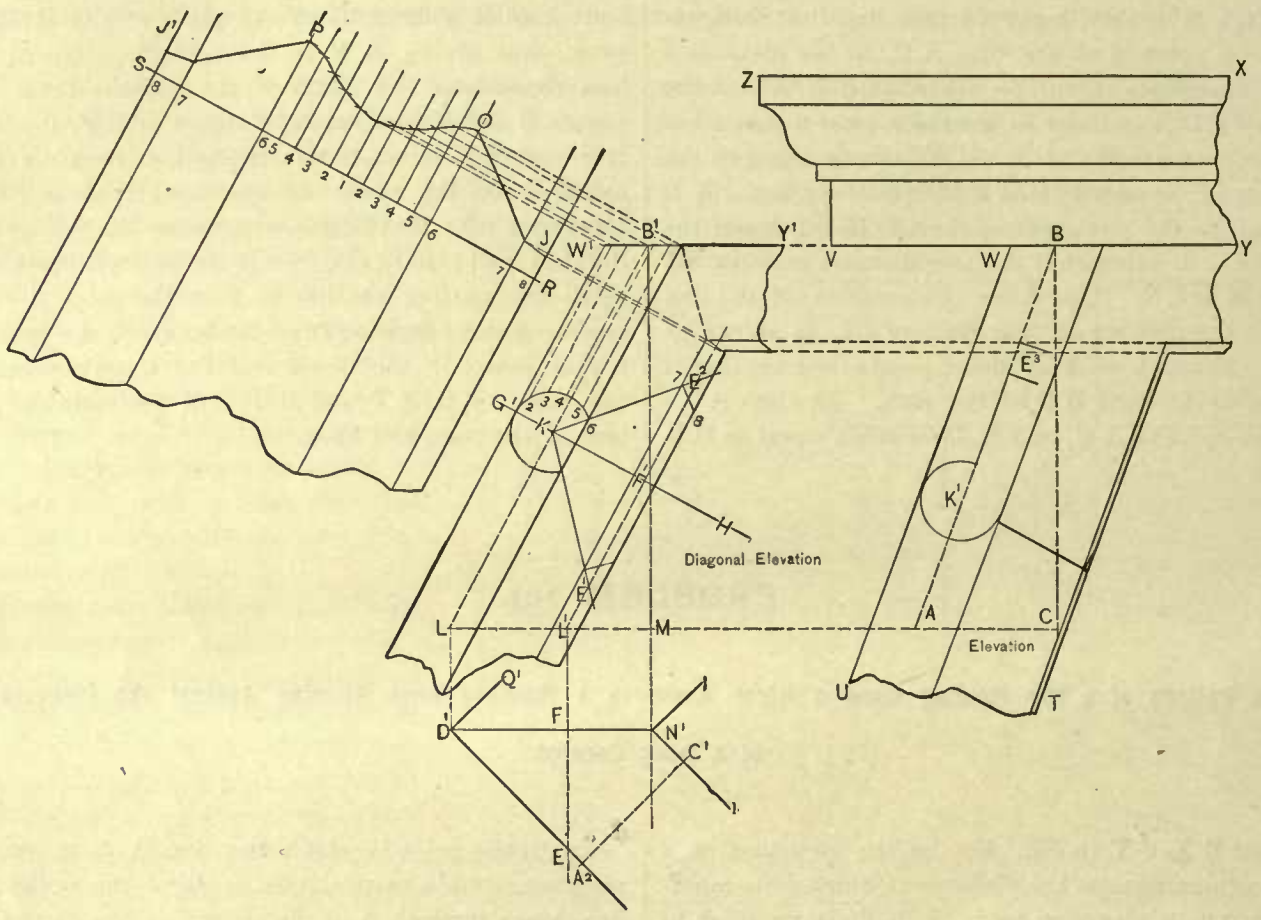


Fig. 404.—The Pattern of a Hip Molding in a Mansard Roof, Mitering Against the Planceer of a Deck Cornice.

K as a center describe the curve of the roll of the required diameter. Upon the lines K E' and K E' set off from K a distance sufficient to make the desired width of fascia, thus completing the profile of the hip molding in the diagonal elevation.

Space one-half of this profile, as G E', in the usual manner, through the points in which carry lines parallel to L B', cutting the line of planceer W' Y', which

is the miter line of the roll. The edges of the fascia will of course miter with the lower edge of the fascia

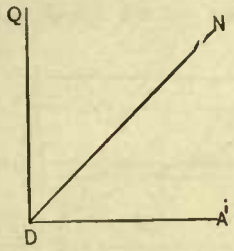


Fig. 405.—Plan of the Fascias and Angle of the Mansard Shown in Fig. 404.

at the top of the mansard, shown in profile at B E³, all as shown by the dotted lines projected from E³. At right angles to the line L B¹ draw the straight line S R, upon which lay off a stretchout of the profile in the usual manner, and through the points draw measuring lines. With the T-square parallel to this stretchout line, or, what is the same, at right angles to the lines of the molding in the diagonal elevation, and, bringing it successively against the points in W¹ Y¹, cut corresponding measuring lines drawn through the stretchout. The measuring lines 7 and 8 are cut from the intersection of the fascia of the hip with lines projected from E³ as above explained. Then a line traced through these points, as shown in the engraving, as shown by J¹ P O J, will be the pattern of the hip molding mitering against the horizontal planceer.

PROBLEM 102.

The Pattern for a Hip Molding upon a Right Angle in a Mansard Roof, Mitering Against a Bed Molding at the Top.

Let A C B, in Fig. 406, be the section of a portion of a mansard roof, the elevation of which is shown to the left, and let P E be any bed molding whose profile does not correspond to or member with the molding used to cover the hips, a section of the hip molding being shown at Z Y C¹.

The solution of this problem will be accomplished by means of a "true face" of the roof, rather than by means of a diagonal elevation as in the problem immediately preceding this. Therefore, supposing the section A C B to give the correct pitch of the roof, the first step will be to obtain the true face, or elevation of the roof as it would appear if tipped or swung into a vertical position, for the purpose of getting the correct angle at A¹ B¹ F¹.

To do this reproduce the section of mansard and bed molding as a whole at a convenient point below, but so turned as to bring the faces of the roof into a vertical position, maintaining the same distance between the points A and B as shown by A² and B². Project lines horizontally to the left from this section for the true face, marking the lines from the points A² and B². From A of the original section carry a line across intersecting the line A¹ B¹ at the point A¹. Next drop line from A¹ and B¹ vertically intersecting lines of corresponding letter, as shown by the dotted lines. Then A³ B³ F¹ will be the correct angle upon which to construct the corner piece and develop the miter line between the hip molding and the bed molding of the deck cornice.

The next step will be to obtain a correct section of the hip molding upon a line at right angles to the line of the hip. To do this it is necessary to first construct a diagonal section through the hip. At any convenient place lay off a plan of the angle of the roof, as shown by D¹ F D² in Fig. 407, and through this angle draw a plan of the hip, as shown by F K. From D¹ erect a line perpendicular to F D¹, as D¹ C², in length equal to D C of the section. Through C², parallel to D¹ F, draw C² K, producing it until it cuts the line representing the plan of the hip. From the points F and K in the lines representing the plan of the hip erect perpendiculars, as shown by F L and K C³. Draw L C¹ parallel to F K, as shown at the base line of a diagonal section. From C³ erect a perpendicular, C³ E¹, in length equal to C E of the original section. Connect E¹ L. Then L C³ E¹ will be a diagonal section of a portion of the roof, and L E¹ will be the length of the hip through that portion. At right angles to L E¹ draw M H¹, upon which to construct a correct section of the hip molding. Take any point, as G in the line F D¹, at convenience, and from it erect a perpendicular

to F K, cutting F K in the point H, and produce it also until it cuts the base line of the diagonal section L C³, as shown, and from this point carry it parallel to the line L E', representing the pitch of the hip, until it will be obtained by which the angle contained between the facias of the hip molding may be determined. Therefore from H' on either side set off the distance H G of the plan, as shown by G' and G². Through

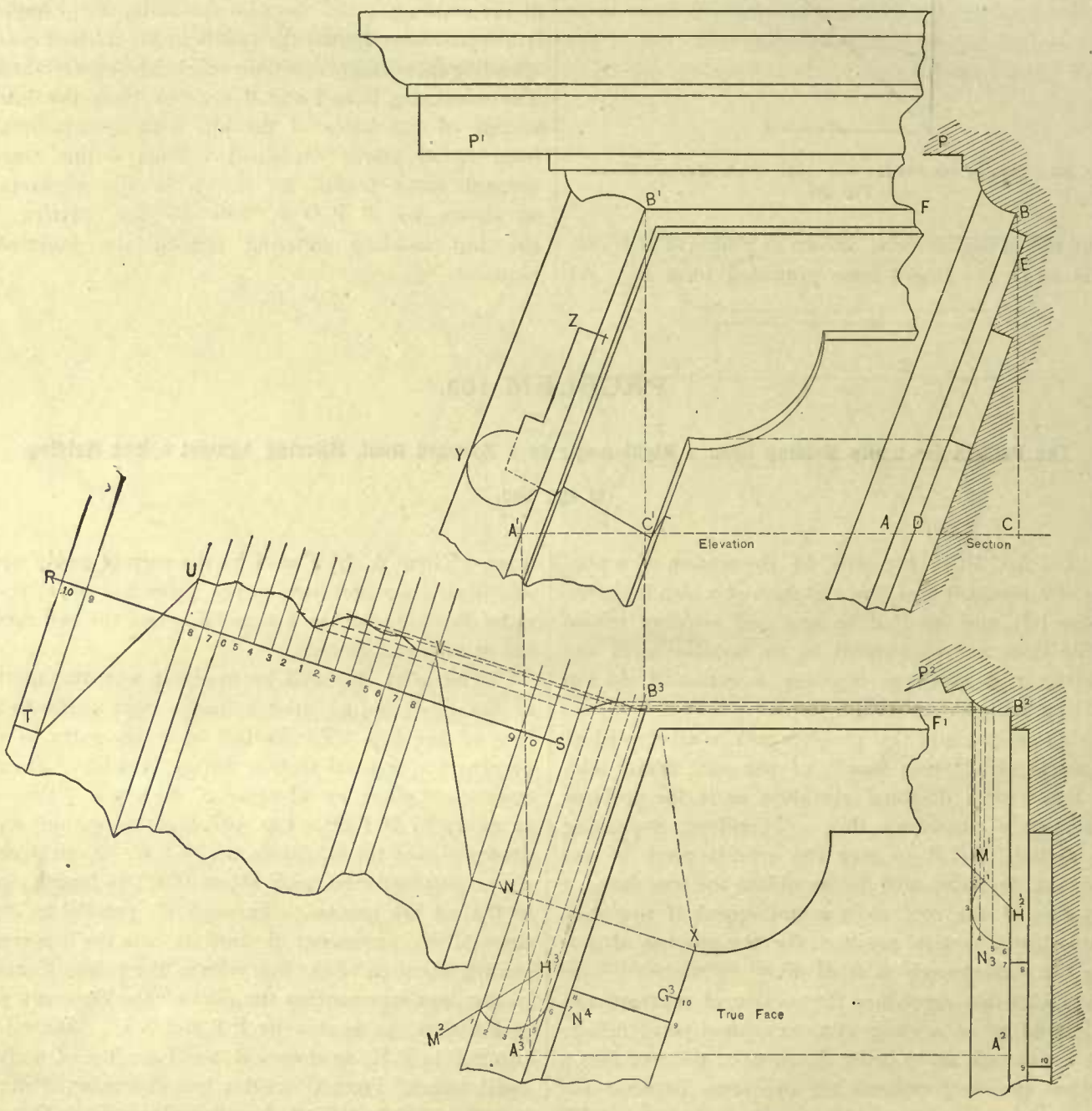


Fig. 406.—The Pattern of a Hip Molding Upon a Right Angle in a Mansard Roof, Mitering Against a Bed Molding.

crosses the line M H', cutting it in the point H'. Since D' F D² represents the angle in plan over which the hip molding is to fit, and since H G is the measurement across that angle, if the distance H G be set off from H' either way in the diagonal section, points these points draw lines representing the fascias of the hip molding, as shown by O G' and O G². Add the fillets and draw the roll according to given dimensions, all as shown.

In the true face, Fig. 406, draw a half section of

the hip molding as derived from Fig. 407, as shown. M^2 H^2 corresponds to M H^1 of the diagonal section.

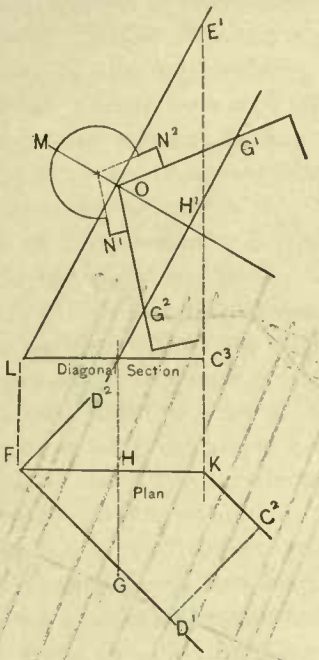


Fig. 407.—Method of Obtaining Correct Cross Section of Hip in Fig. 406.

Space this profile into any convenient number of parts in the usual manner, and through the points draw lines parallel to the lines of the hip molding indefinitely. Place a corresponding portion of the profile of the hip molding in the vertical section, as shown, in which M^1 H^2 also corresponds to H^1 M in the diagonal section. Divide this section into the same number of equal parts, and through the points draw lines upward until they intersect with the profile of the bed molding, as shown between P^2 and B^2. From the points in P^2 B^2 carry lines horizontally, intersecting the lines drawn from the profile in the true face. Then a line traced through these points of intersection will be the miter line between the hip molding and the bed molding, as seen near B^3 in elevation.

For the pattern proceed as follows: At right angles to the line of the hip molding, as shown in the true face, lay off a stretchout of the hip molding, as shown by S R, through the points in which draw the usual measuring lines. Place the T-square at right angles to the lines of the hip molding, and, bringing it successively against the several points in the miter line, as shown in elevation, cut corresponding measuring lines, which will give the pattern for the roll and fillets, as shown from U to V. In like manner place the T-square against the point X in the true face, which is the point of junction between the flange of the hip molding and the apron of the bed molding corresponding to points 9 and 10 of the profile, and cut the corresponding measuring lines. The pattern is then completed by drawing a line from W to V and T to U.

PROBLEM 103.

Patterns for the Top and Bottom of the Hip Bar in a Skylight.

In the upper part of Fig. 408 is shown the transverse section of a skylight in which A B represents a portion of the ventilator or finish at the top, and C D the curb or finish at the bottom. The section also shows the side elevation of a "common" bar whose profile is at F. The plan immediately below shows a corner of the skylight with one of the hip bars, H K, the patterns for which are required. It will be necessary first to see that the plan is correctly projected from the elevation, and afterward that a diagonal elevation of the hip bar be obtained from this plan, before the correct or raked profile of the hip bar can be obtained.

Draw a duplicate of normal profile F with its center line on the center line of the hip, as shown at F', as a means of obtaining the lateral projection of all its points, numbering corresponding points in both profiles the same. Number the intersections of all the points in the normal profile F with the top and bottom of the skylight finish, as shown by the small figures in A B and C G. From each of the points in the profile F carry lines parallel to the center line of the hip in either direction, intersecting lines of corresponding number dropped vertically from both the miters of the transverse section to the plan. Lines traced through these points of intersection will give the miter lines at top and bottom as they appear in plan.

At right angles to the lines of the hip carry lines, as shown, by means of which to construct the diagonal elevation. Assume any line, as E' G', as the base or

horizontal line of the diagonal elevation representing E G of the section. At E' ereet a perpendicular upon the horizontal molding at the top whose profile is shown at A B, it will be found most eonvenient to

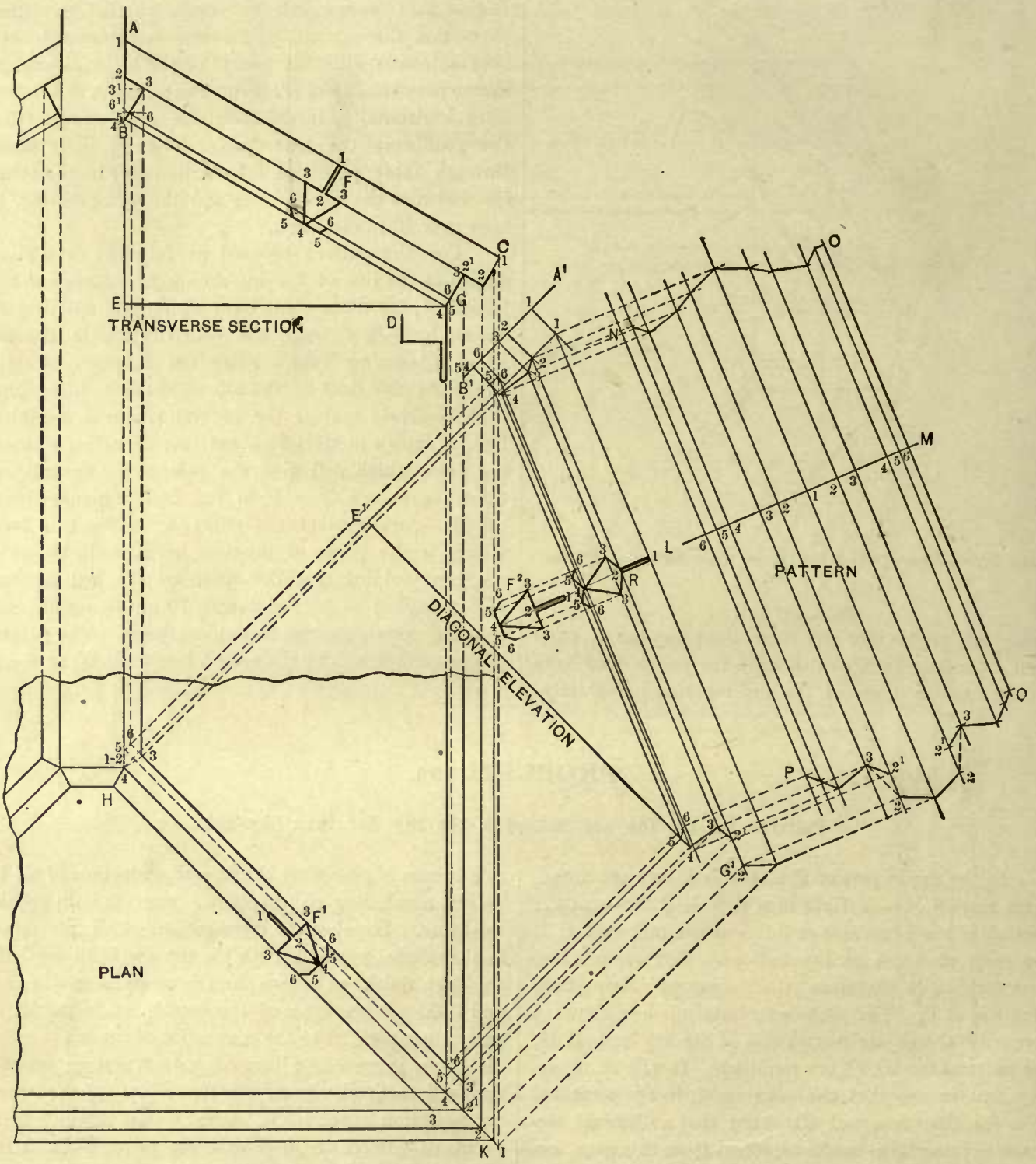


Fig. 408.—Plan and Section of a Skylight and Patterns for the Hip Bar.

which to obtain the hights of the various points in the upper miter. As the hip bar is required to miter with earry all the points of the upper profile to the vertieal line A B, as shown by 1, 2, 3', 4, 5 and 6', and after-

ward to transfer them, as shown, to the line A' B', keeping the perpendicular hight from E' to B' equal to E B. From all the points in A' B' carry lines horizontally—that is, parallel to E' G'—to the right indefinitely, as shown. These lines will then represent a partial elevation of the top molding A B in the diagonal elevation. Lines from each of the points in the plan of the upper miter at H may now be carried parallel to H E' until they intersect with lines of corresponding number drawn from A' B'. Lines connecting the points of intersection will give the required miter line at the top of the hip bar.

From each of the points obtained in this miter line carry lines parallel to B' G', or the rake of the hip bar, and intersect them with lines projected parallel to H E' from the lower miter in plan at K. Lines connecting these points of intersection will give the required miter line at the bottom of the hip bar.

It now remains only to obtain the correct profile of the hip bar before a stretchout can be obtained. To accomplish this, draw any line cutting the lines of the hip bar in the diagonal elevation at right angles, as shown at R. Upon this line, and above or below the hip bar, as shown at F', draw a duplicate of the normal profile F, from the points in which carry lines at right angles to the hip bar, cutting lines of corresponding number in the same. Then lines connecting the points of intersection will give the raked profile, as shown at R.

On account of limited space the important details in Fig. 408 are necessarily small, but great care has been taken in the preparation of the drawing, and all the points in the several views of both miters have been carefully numbered, so that the reader will have no difficulty in following out the various intersections from start to finish. The profile and the two miter lines now being in readiness, the pattern may be developed in the usual manner, as follows: Upon any line drawn at right angles to the hip bar, as L M, lay off a stretchout of the profile R, as shown by the small figures, through which draw the measuring lines. Keeping the blade of the T-square parallel with L M, bring it successively against the points of intersection previously obtained in the upper and lower miters and cut corresponding measuring lines. Then lines traced through the various points of intersection, as shown by N O and P Q, will constitute the required patterns.

It may be noticed that while most of the points from the normal profile F come squarely against the inner beveled surface of the curb G, the points 1 and 2, representing the vertical portion of the bar, pass over the curb to a point beyond. The line from point 2, therefore, intersects at both 2 and 2', which points are duly carried through the views of this miter at K and G' and finally into the pattern, as shown; from which it may be seen that the miter pattern may be cut as shown by the solid line from P to Q, or that portion from point 2 to 3 may be cut as shown by the dotted line.

PROBLEM 104.

Pattern for the Top of a Jack Bar in a Skylight.

The jack bar in a skylight is the same as the "common" bar in respect to its profile, and the miter at its lower end with the curb. At its upper end, however, it is required to miter against the side of the hip bar instead of against the upper finish of the skylight. As the hip bar occupies an oblique position with reference to the jack bar, it is evident that a perfect miter between the two could not be effected without a modification or raking of the profile of the hip bar, all of which has been demonstrated in the preceding problem.

It may be here remarked that the raking of the profile of the hip bar is done not so much to affect a perfect joint with the top finish as to make a perfect miter with the jack bar, or what is the same thing, that the surfaces indicated by 2 3 of the profile of the hip bar in Fig. 408 shall lie in the same plane with that portion of the profile of the jack bar. However, as the raked hip bar presents exactly the same appearance when viewed in plan as a bar of normal profile, it will not be really necessary, so far as the miter cut on the jack bar is concerned, to perform the raking operation.

In Fig. 409 is shown a sectional and a plan view of a portion of a skylight containing the miter above referred to. The normal profile of the jack bar shown at F and F' is not exactly the same in its proportions as that of the preceding problem, but possesses the

same general features. The view of the bar given in the section from A to B represents an oblique elevation of that side of the hip bar which is toward the jack bar. From B to D the view shows the side of the jack bar, while beyond D is shown a continuation of the full hip bar with its profile correctly placed in position at F^3.

The first step before the pattern can be laid out is to obtain a correct intersection of the points in the plan, as at B^1, and afterward an elevation of the same, as shown at B. Draw a normal profile of the jack bar in correct position in the plan, as shown at F^1. Also place a profile of the hip bar in the plan of the same, as shown at F^2. As only the lateral projection of the points are here made use of a normal profile will answer as well as the raked profile shown, as above intimated. Number all the points in both profiles correspondingly, and from the points in each carry lines respectively parallel to their plans, intersecting as shown at B^1. From the points of intersection of like numbers erect lines vertically into the sectional view, cutting lines of corresponding number drawn from the points in the profile F parallel to the lines of the rake, as shown near B. It will be seen that both sides of the profile F^1 intersect with one side of the profile F^2, both sets of intersection being numbered alike, as 1^1, 2^1, 3^1, etc. This gives rise to two miter lines at B in the sectional view. The line corresponding to the intersections on the upper side of the jack bar are here numbered 1^2, 2^2, 3^2, etc., while those points belonging exclusively to the lower intersection are numbered 3^3, 5^3 and 6^3.

A stretchout of the normal profile F may now be laid off on any line, as G H, drawn at right angles to the elevation of the jack bar, through which the usual measuring lines are drawn. Now place the blade of the T-square parallel to G H, and, bringing it against the various points in the two miter lines above described, cut corresponding measuring lines, carrying the points from the upper miter line into one side of the pattern and those from the lower one into the other side; then lines connecting the points of intersection, as shown from K to L, will constitute the required miter cut.

As it is desirable to cut the miter on the jack bar so as to fit over the hip bar (that is, so as not to cut the hip bar at all) and in order to prevent the surface from 4 to 5 of the jack bar from lapping on to a like portion of the hip bar, as shown between the points 4', 5' and x in the plan, the line from point 4 of F^1 is allowed to intersect with the line from 5 of F^2, as shown at x, which point is carried into the sectional view and thence into the pattern, where it intersects with lines 4, as shown by x, so that the cut in the pattern is from x to 5 instead of from 4 to 5. For the same reason,

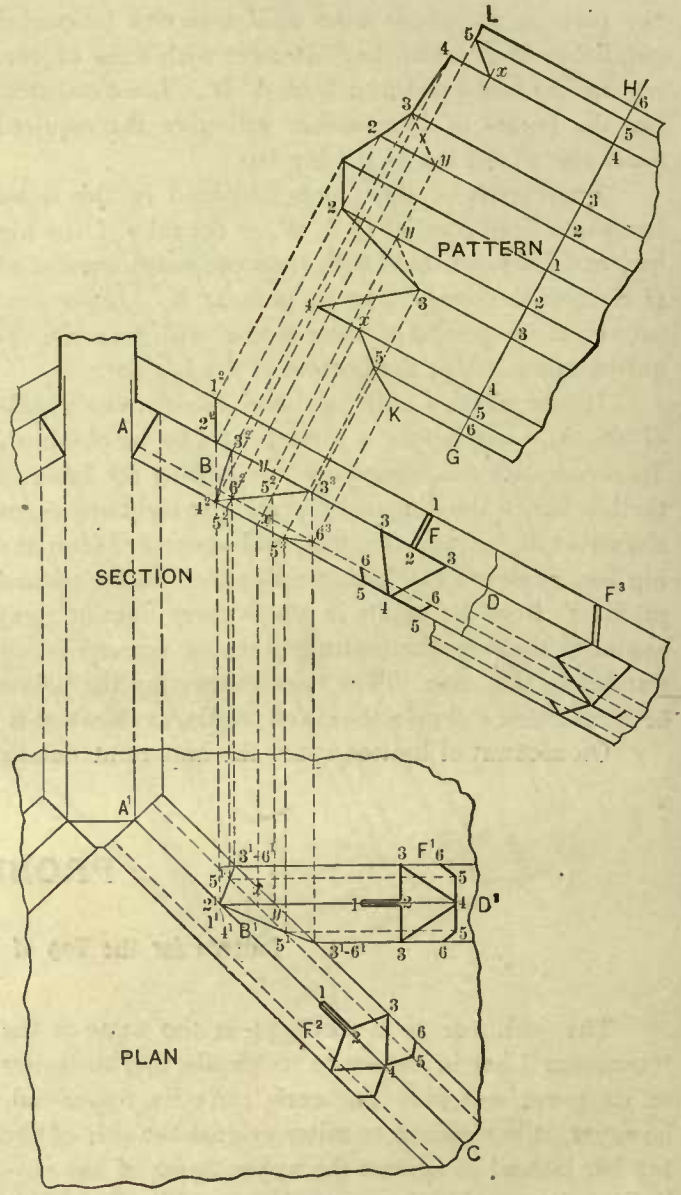


Fig. 409.—Section and Plan of Miter at the Top of the Jack Bar in a Skylight and Pattern of the Same.

if it is desired to prevent the surfaces 2 3 from overlapping the line from 2 of F^1 may be intersected with 3 from F^2, as shown at y, and carried into the pattern, as shown, producing the cuts in the pattern shown by the dotted lines 3 y in the place of those shown from 3 to 2.

PROBLEM 105.

The Pattern of a Hip Mold Upon an Octagon Angle in a Mansard Roof, Mitering Against a Bed Molding of Corresponding Profile.

This problem, like many others pertaining to mansard roofs, may reach the pattern cutter in drawings either more or less accurate, and in different stages of completion. Certain facts, however—viz., the profiles of the moldings, the pitch of the roof and the angle in plan—must be known before the work can be accomplished; but with these given the pattern cutter will have no difficulty in drawing such elevations as are necessary to produce the required patterns.

In Fig. 410, let A B C D be the given section of the mansard trimming shown, A C the profile of the bed molding and apron, and B D E the pitch of the roof. According to the statement of the problem above the angle of the plan is octagonal; it might be a special angle either greater or less than that of an octagon, but the principle involved and the operation of cutting the patterns would be the same. As in all other problems connected with mansard trimmings, the first requisite is an elevation of the "true face," in order to obtain the correct angle between the bed molding and the hip molding. A normal elevation, such as is likely to be met with in the architect's drawings, is shown in the engraving at the left of the section, merely for purposes of design. In obtaining the true face, shown below, it is best to use the section and plan only. Therefore, redraw the section as shown immediately below it, placing the line of the roof in a vertical position, all as shown. From all the points of this section lines may now be projected horizontally to the left, as the first step in developing the required true face. Immediately above the space allotted to the elevation draw a plan of the horizontal angle, as shown by I E' K. As it will be impracticable to include the entire profile of the roof in the drawings, some point must be assumed at a convenient distance below the bed mold, as D, from which to measure hight and projection, which locate also in the section below, as shown at D', making B' D' equal to B D. From A draw a line at right angles to the line of the roof, meeting it at B, which point may be assumed for convenience as the upper limit of that part of the roof under consideration. Now, from the point B drop a vertical line, which intersect with one drawn horizontally from D, as shown at E; then D E will represent the projection. From the lines I E' and E' K, upon lines at right angles to each, set off the projection D E, as shown at I F and K H; through the points F and H draw lines parallel to the first lines, meeting in G; then a line from G to H will represent the plan of the angle or hip of that portion of the roof of which B D is the profile. Now, to complete the true face of that part of the roof drop a line from the point E' intersecting the line from B' at L, and one from G intersecting the one from D' at M; then the angle B' L M will be the correct angle of the miter between the bed mold and the hip mold.

As in Problems 101 and 102 preceding, it will next be necessary to obtain a correct section of the hip mold on a line at right angles to the line of the hip. To avoid confusion of lines, this operation is shown in Fig. 411, in which E² G', the base line, is made equal to E' G of the plan in the previous figure. At the point E² erect a perpendicular, making it equal in hight to B E of the sectional view. Connect B² with G', which will give the correct angle of the hip of the roof. As a means of constructing a correct section at right angles to this line, assume any two points on the original plan, as N and O, equidistant from G and connect them by a straight line, cutting the angle or hip line in P. Set off from G' on the line G' E² of Fig. 411 a distance equal to G P of the plan, as shown at P', from which draw a line parallel to the hip G' B². Next intersect these two lines by another at right angles at any convenient point, as shown by P² Q. From the point P² set off the distances P² O' and P² N', making them equal to P O and P N. Connect the points O' and N' with R, which is the intersection of P² Q with the hip line; then the angle O' R N' will be a correct section of the roof upon the line P² Q or upon any line cutting the hip at right angles, upon which the finished profile of the hip mold may now be constructed as follows: Set off the projections of the fascia and fillet as given in the sectional view, Fig. 410, from the lines R O' and R N', continuing their lines to the center line P² Q. From the intersection S as a center, with a radius of the bed mold, describe the roll.

As stipulated in the statement of this problem, the profiles of the bed mold and hip mold are to cor-

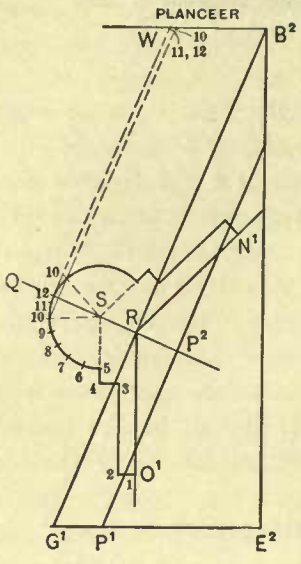


Fig. 411.—Diagonal Section of Hip.

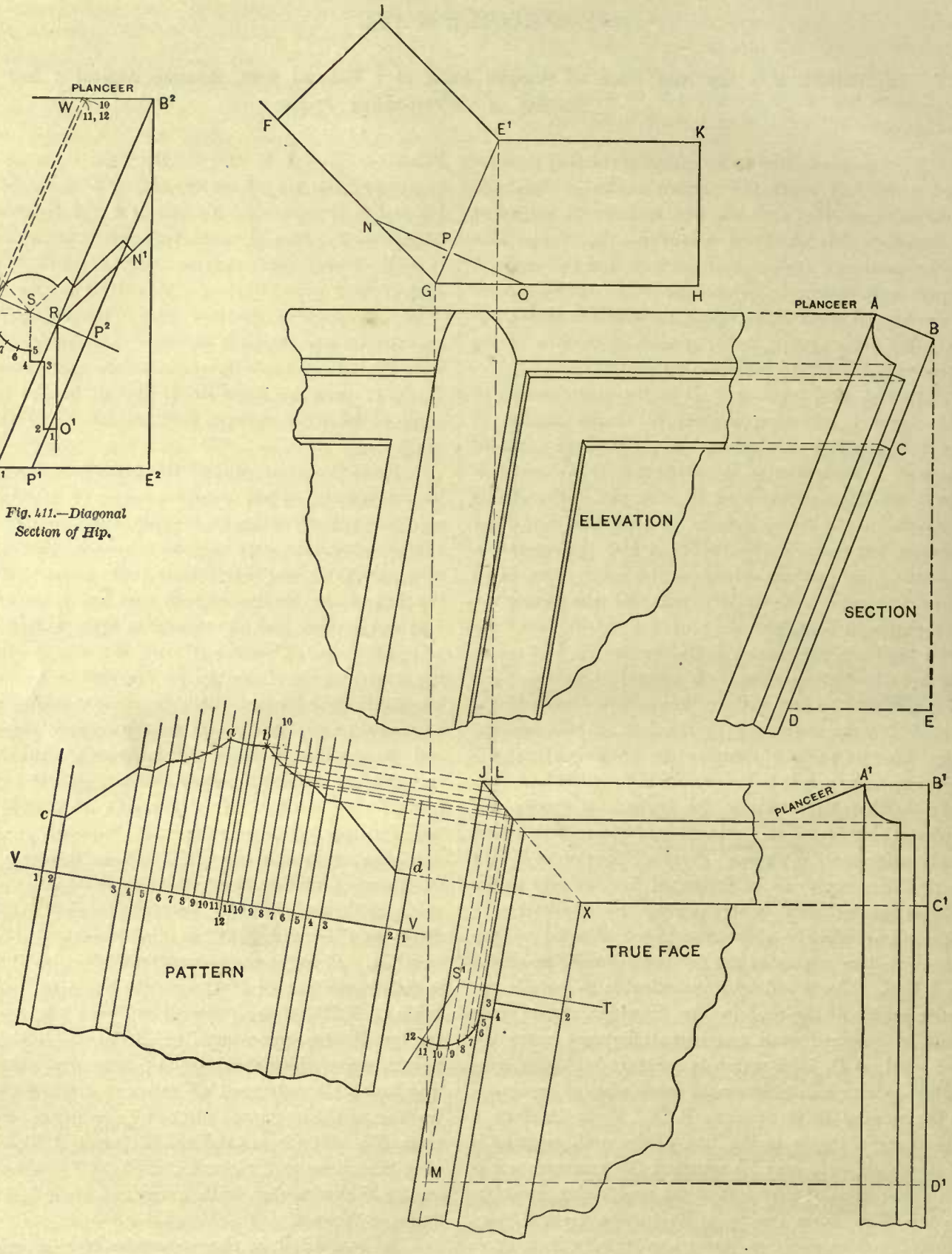


Fig. 410.—The Pattern of a Hip Molding Upon an Octagon Angle, Mitering Against a Bed Molding of Corresponding Profile.

respond. By this it is understood that the curves of their molded surfaces are alike and struck with the same radius, and so placed as to member or miter.

As the curve of the bed mold is only a quarter circle, while that of the hip mold is nearly three-quarters of a circle, it will be seen that the quarter circles in each half of the hip mold next adjacent to the fascias and fillets will miter with the arms of the bed mold on either side of the miter, and that a small space in the middle of the roll will remain between them, which must be mitered against the planceer, and the object of the operation shown in Fig. 411 is to determine exactly what this space is. The dotted lines from S to the points 10 drawn at right angles to R O' and R N' show the limit of the quarter circles or the parts that must miter with the bed mold, while the space between them (10 to 10) shows the part that must miter against the planceer. It might be supposed that the angle between the fascias of the hip mold, to fit over the angle of a mansard which is octagonal in plan, would be octagonal, but the demonstration shows that while the angle N G O of the plan, Fig. 410, is that of an octagon, the angle N' R O', Fig. 411, is greater, because the distance N' O' is equal to N O, while the distance R P² is less than G P, R P² being at right angles to the line of the hip and G' P' being oblique to it.

The true face, Fig. 410, may now be completed, as follows: Upon any line, as S' T, drawn at right angles to L M, representing the face of the roof, draw a duplicate of one-half the profile of the hip mold obtained in Fig. 411, placing the point S upon the line L M, as shown. Lines drawn through the angles of this profile parallel to L M will intersect with lines from corresponding points from the profile A' C', previously drawn, giving the miter line J X and completing the elevation of the true face.

Upon any line at right angles to the line L M, as U V, lay off a stretchout of the complete hip mold as obtained from the half profile S' T, through which draw measuring lines as usual. Drop lines from the points from 1 to 10 of the profile, parallel to L M, cutting the miter line; then, with the T-square placed at right angles to L M and brought successively against the points in J X, intersect them with lines of corresponding number in the stretchout; then lines traced through the points of intersection, shown by *d b* and *a e*, will give the pattern for that part of the profile from 1 up to the point 10. The pattern of that portion of the roll which miters against the planceer must be obtained from the diagonal section of the hip. From points 10, 11 and 12 in Fig. 411 carry lines parallel to G' B² intersecting the line of the planceer, as shown at W. It is only necessary to ascertain how much shorter the lines 11 and 12 are than the line 10, and then to transfer these distances to the pattern. This can be done by dropping lines from the intersection of points 11 and 12 with the planceer, in Fig. 411, at right angles to G' B², cutting line 10. These distances can then be transferred to line 10 of the pattern, Fig. 410, measuring down from the point 10 of pattern already obtained, after which they may be carried parallel to U V into the measuring lines 11 and 12, thus completing the pattern.

This portion of the work is necessarily very minute in the drawing, but it will be easily seen, in applying the principle to other similar cases, that if the angle of the plan I E' K were less than that shown, for instance, if it were a right or an acute angle, a greater distance or more points would occur between the points 10 and 10, and further, that if the angle of the roof were less steep a greater curve or dip would occur between those points (*a* to *b*) of the pattern.

PROBLEM 106.

The Pattern of a Hip Molding Upon an Octagon Angle of a Mansard Roof, Mitering Upon an Inclined Wash at the Bottom.

In Fig. 412, let D B of the section represent the wash surmounting the base molding at the foot of a mansard roof, the inclination of the roof being shown by B A. The plan of the angle of the roof B² K B², as specified, is that of an octagon, but so far as principle and method are concerned, it may be any angle whatever. The profile of the hip mold as given in the original drawings will most likely be drawn as fitting over an octagonal angle—that is, over the angle as given in the plan of the building. As explained in the problem preceding this, a section through the angle of the roof at right angles to the line of the hip must be

Fig. 413.—Diagonal Section of Hip.

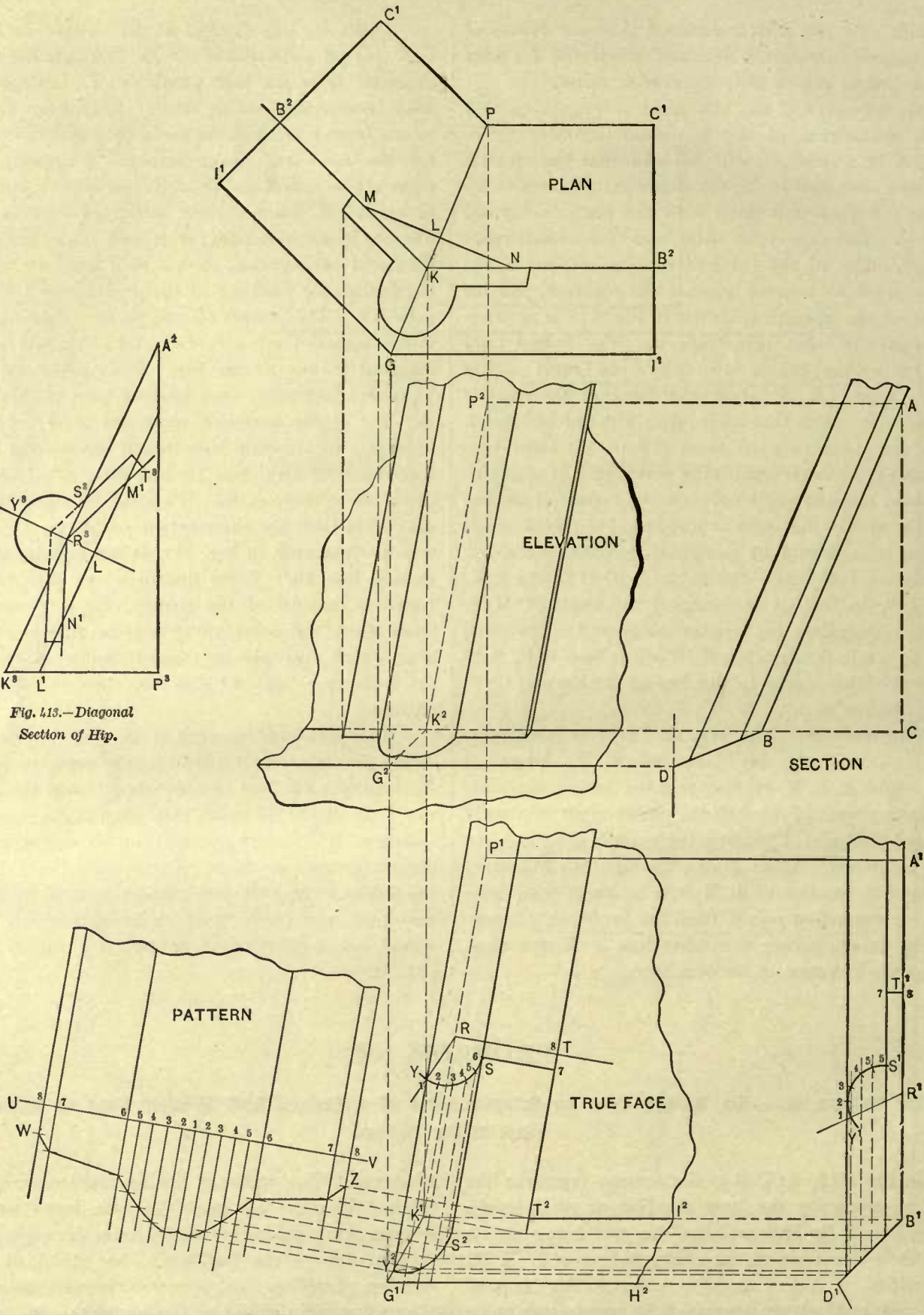


Fig. 412.—The Pattern of a Hip Molding Upon an Octagon Angle, Mitering Upon an Inclined Wash at the Bottom.

obtained, to which the profile of the hip mold must be adjusted before going ahead. The difference between such a section and the angle in plan may seem trifling, but will be found to increase as the pitch of the roof decreases, and in a low hip roof will be found to be considerable. Hence the original detail of the hip mold must be accepted only so far as it gives width and depth of fascias and fillets, and diameter or radius of the roll, while the angle between the fascias must be adjusted to the true section across the hip as above stated. The method of doing this is shown in Fig. 413, and the principles involved therein are explained in the previous problem in connection with Fig. 411, and need not, therefore, be repeated here.

The first operation will consist in obtaining the "true face" of the roof in the usual manner, viz.: Assume any point upon the section of the roof, as A, at a convenient distance above the base, as a point from which to measure hight and projection. Redraw the section of the roof immediately below the first one, placing it in a vertical position and locating thereon the point A, as shown by A^1. From the points A^1, B^1 and D^1 project lines horizontally to the left, thus obtaining all the hights in the true face. It will be necessary next to complete the plan, to do which first obtain the projection of the points in the section upon any horizontal line, as the one drawn through B, which can be done by dropping vertical lines from the points A and D, cutting it as shown at I and C. Assuming the line B^2 K B^2 of the plan to represent the point B of the section, set off upon any lines at right angles to the lines B^2 K these projections—that is, make B^2 I^1 equal to B I, and B^2 C^1 equal to B C. Through these points draw lines parallel to B^2 K, intersecting and forming the line P G, which is the plan of the angle over which the hip mold is required to fit. From the points P, K and G, which represent upon the angle of the roof the points A, B and D of the section, drop lines vertically into the true face intersecting the horizontal lines previously drawn from A^1, B^1 and D^1, as shown; then P^1 K^1 I^2 will be the correct angle at which to construct the miter of the half of the hip mold belonging to this face of the roof, and K^1 G^1 H^2 I^2 will represent a corresponding elevation of the wash.

The elevation of the true face may now be completed by placing one-half the profile of the hip in correct position—that is, with its base line or fascia at right angles to the hip line P^1 K^1, the point R coming on the line. Through the points Y, S and T project lines parallel to the hip line. To show the intersection of the hip mold with the wash, first place a duplicate of the half profile of hip mold in the sectional view, as shown by Y^1 R^1 T^1; then divide the curved portion of both profiles into the same number of equal spaces and number all the points correspondingly, as shown. From these points drop lines downward parallel with the lines of the respective views, those in the sectional view cutting the line of the wash B^1 D^1. From these points of intersection carry lines horizontally, intersecting the lines dropped from the profile Y S T. Then a line traced through these points of intersection, as shown by Y^2 S^2 T^2, will be the miter line formed by the junction of the hip molding with the wash. At right angles to the line of the hip molding in the true face lay off a complete stretchout of the hip molding, as shown by U V. Through the points in it draw measuring lines in the usual manner. Place the T-square parallel to this stretchout, or, what is the same, at right angles to the line of the hip molding, as shown in true face, and, bringing it successively against the points in the miter line Y^2 S^2 T^2, cut the corresponding measuring lines. Then a line traced through these points of intersection, as shown from W to Z, will be the cut to fit the bottom of the hip molding.

The normal elevation may be completed, if desired, by means of projections from the plan and the section, as shown.

PROBLEM 107.

Pattern for a Hip Molding Mitering Against the Planceer of a Deck Cornice on a Mansard Roof Which is Square at the Eaves and Octagon at the Top.

In Fig. 414 is shown the method of obtaining the miter against the planceer of a deck cornice formed by the molding covering a hip, which occurs between the main roof and that part which forms the transition from a square at the base to an octagon shape at the top. The roof is of the character sometimes employed

upon towers which are square in a portion of their hight and octagon in another portion, the transition from square to octagon occurring in the roof. The hip molding in question covers what may be called a transition hip, being a diagonal line starting from one of the corners of the square part and ending at one of the corners of the octagon above. A carefully drawn plan, together with a section through one of the sides of the roof, giving the pitch, will be the first requisites to solving the problem, both of which are shown in the engraving. The first operation will be the construction of a section upon the line of the hip, which may be done as follows: Assume any point, as A, in the section of the roof from which to measure hight and projection. If a horizontal line from A and a vertical line from the top of the roof surface B be intersected in C, then B C will represent the hight and A C the projection of the part of the roof assumed. Set off the projection C A at right angles to the top line of the plan C' E, as shown by C' A', and carry a line through A' parallel to C' E till it cuts the plan of hip E Q at D; then D E will form the base and B C the hight of the required section, which may be obtained for convenience by lines projected from D E at right angles, all as shown. The line B' D' then represents the real angle at which the hip mold meets the planceer or level line at the top.

The next operation will consist in obtaining a correct section of the hip mold from the data given and in placing it in correct position in the diagonal section. Take any point, G, in the plan at a convenient distance from the angle W D A'. Set off G' at the same distance from the angle on the opposite side. From the points G and G' carry lines at right angles to and cutting D' C' in the points H' and O', and from these points carry them parallel with the line D' B' indefinitely. At right angles to D' B' draw a line, as shown by Z H', intersecting with the lines last drawn in the points H' and O. From H', along the line H' H', set off a distance equal to H G of the plan, and from O, in the line Z H', set off a distance equal to O' G' of the plan, as shown by O G'. Connect the intersection of Z H' and D' B' with the points G' and G', which will give the correct section through the angle of the roof. Having thus determined the angle of the hip molding finish, a representation of it is indicated in the drawing by adding the flanges and the roll. Since the miter required is the junction between the hip molding, the profile of which has just been drawn, and a horizontal planceer, the remaining step in the development of the pattern consists simply in dividing the profile into any convenient number of parts, and carrying points against the line of the planceer, as shown near B', and thence carrying them across to the stretchout, as indicated. It is evident, however, upon inspection of the elevation, that the apron or fascia strips in connection with the planceer which miter with the flanges of the hip molding will form a different joint upon the side corresponding to the transition piece of the roof than upon the side corresponding to the normal pitch of the roof, owing to the difference in pitch of these two sides. To obtain the lines for this miter an additional section must be constructed, corresponding to a center line through the transition piece, as shown by W L in plan. Prolong C' D', as indicated, in the direction of W', and lay off W' L', equal to W L of the plan. From L' erect a perpendicular, as shown by L' B', equal to C B of the original section. Connect W' and B', against the face of which draw a section of the apron or fascia strip belonging to the planceer, as shown, and from the points in it carry lines parallel to B' B' until they intersect lines drawn from the flange of the hip molding lying against that side of the roof, all as indicated by U X. From these points carry lines, cutting corresponding lines in the stretchout. The lines of the fascia belonging to the other side are the same as if projected from the normal section at B, or as they appear in the elevation. Having obtained these points proceed as follows: At right angles to the lines of the molding in the diagonal section lay off the stretchout of the hip molding S T, and through the points draw the usual measuring lines, as shown. Place the T-square at right angles to the lines of the molding, or, what is the same, parallel to the stretchout line, and, bringing it successively against the points formed by the intersection of the lines drawn from the hip molding and the planceer line B', cut the corresponding measuring lines, as shown. In like manner bring the T-square against the points U and X, above described, and Y and V, points corresponding with the opposite side of the hip molding, and cut corresponding lines. Then a line traced through these several points of intersection, as shown by U' X' Y' V', will be the pattern sought.

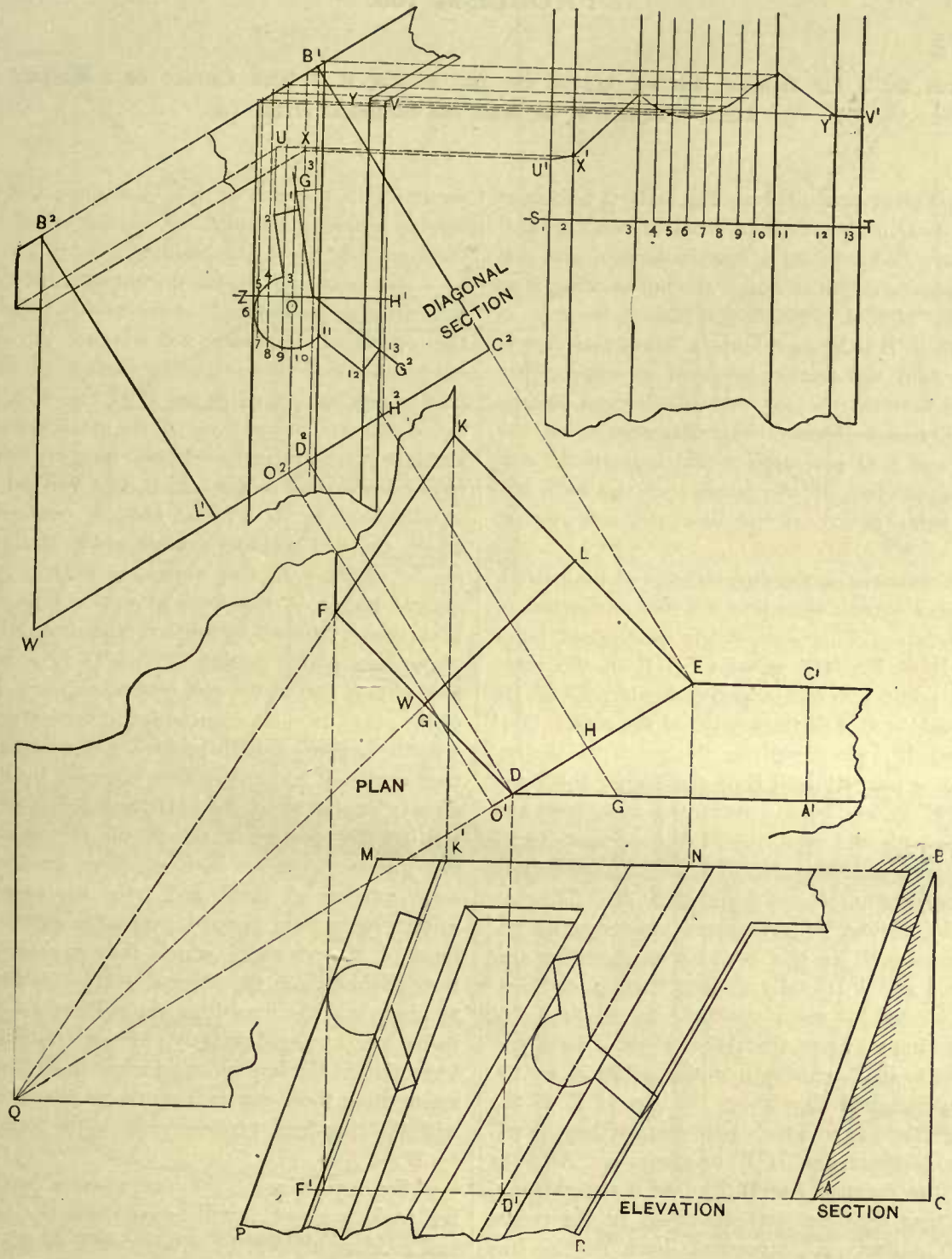


Fig. 414.—The Pattern for a Hip Molding Mitering Against the Planceer of a Deck Cornice on a Mansard Roof Which is Square at the Eaves and Octagon at the Top.

PROBLEM 108.

Patterns for a Hip Molding Mitering Against the Bed Molding of a Deck Cornice on a Mansard Roof which is Square at the Base and Octagonal at the Top.

The problem presented in Fig. 415 is similar to that described in the previous problem, with the difference that a bed molding is introduced in connection with the planceer against which the hip molding is to be mitered. M E M¹ represents a plan of the roof at the top, while L D M² represents a horizontal line at the point A of the section, assumed at convenience somewhere between the top and the bottom for the purpose of measurement. The intersection of the lines M L and E D prolonged would indicate the corner of the building at the bottom of the roof, the structure being square at the base and octagonal at the top.

The first step in the development of the pattern is to obtain a correct section of the roof on the line of one of the hips. Therefore, at any convenient point lay off E^2 D^2 of Fig. 416 equal to D E of the plan. From the point E^2 erect a perpendicular, E^2 B^2, in length equal to C B of the section of the roof. Connect B^2 and D^2, which will be the pitch of the hip corresponding to the line D E of the plan. Since the section D^2 E^2 B^2 has been constructed away from and out of line with the plan, it will be necessary to reproduce a portion of the plan in immediate connection with the section, as shown by I¹ II A^2 C^2. This can be done by tracing, or any means most convenient. From the point II in this plan lay off on either arm the points I and I', equally distant from it and conveniently located for use in constructing the profile of the hip molding. From the points I and I' erect perpendiculars to II C^2, cutting it in the points K and O, which prolong until they meet the base D^2 E^2 of the diagonal section, from which points carry them parallel to the inclined line D^2 B^2 indefinitely. At right angles to the inclined line D^2 B^2 draw a straight line, O¹ K¹, cutting the lines last described in the points K¹ and O¹. From K¹, measuring back on the line I^2 K¹, set off the point I^2, making the distance from K¹ to I^2 the same as from K to I of the plan. From O¹ in the line I¹ I^2 set off the distance O¹ I^2, equal to O I¹ of the plan. From these points I^2 and I^2 draw lines meeting the line O¹ K¹ at the point of its intersection with the line D^2 B^2. Complete the profile of the hip molding, as indicated, laying off the width of the fascias on these lines, adding the roll and edges.

The next step in the development of the pattern is to draw a "true face" of the roof. In performing this operation it matters not whether the actual surface of the roof be used or the surface of the fascias. In this case the points A and B of Fig. 415, by which the depth and projections of the pitch are measured, are taken on the surface of the fascia. For the true face transfer the section A B to a vertical position, as indicated by A^2 B¹, Fig. 415, in connection with which the bed molding against which the hip molding is to miter is also drawn, as shown. From the several points in this vertical section draw horizontal lines, which intersect by vertical lines dropped from corresponding points in plan. Then D^2 E^2 X is the true face of that part of the roof corresponding to D E M¹ M^2 of the plan. In connection with the vertical section just described, place a half profile of the hip molding, a true section of which has been obtained by the process already explained in Fig. 416, and also place a duplicate of this portion of the profile in connection with the true face. Space both of these profiles into the same number of parts, and from the several points in each carry lines upward parallel respectively to the lines of the views in which they appear; the lines from the profile in the vertical section cutting the bed molding, and the lines from the profile in the true face being continued indefinitely. From the points of intersection in the bed molding carry lines horizontally, intersecting those drawn from the profile in connection with the true face, producing the miter line, as shown by E^2.

By inspection of the plan where a portion of the bed mold is shown it will be seen that the miter of the bed molding around the octagon at E is regular—that is, its miter line does not coincide with the line of the hip D E. If the profile of the bed molding in the vertical section, and also the profile of the bed molding as shown in the plan, be divided into any equal umber of parts, points may be dropped from the

n

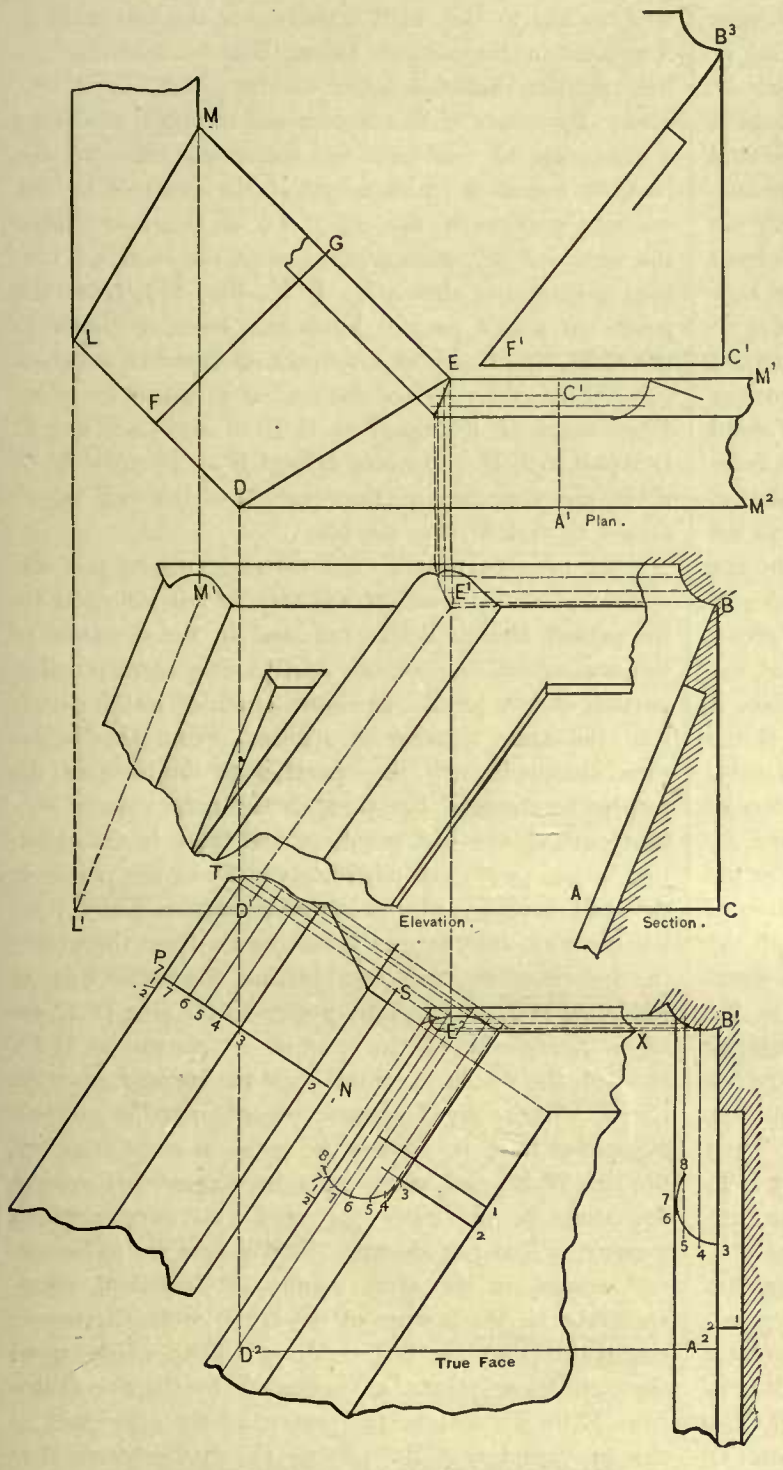


Fig. 415.—Plan, Elevation, True Face and Part of Pattern.

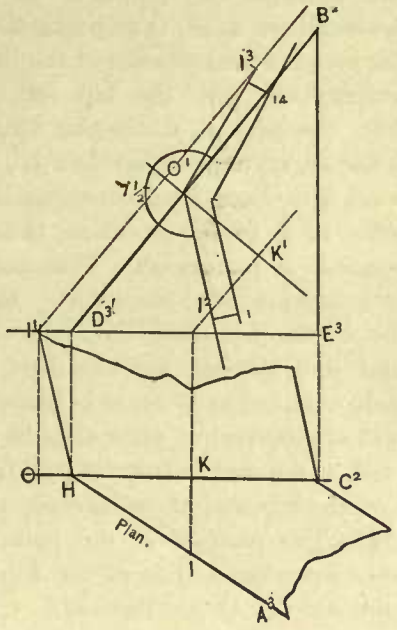


Fig. 416.—Diagonal Section.

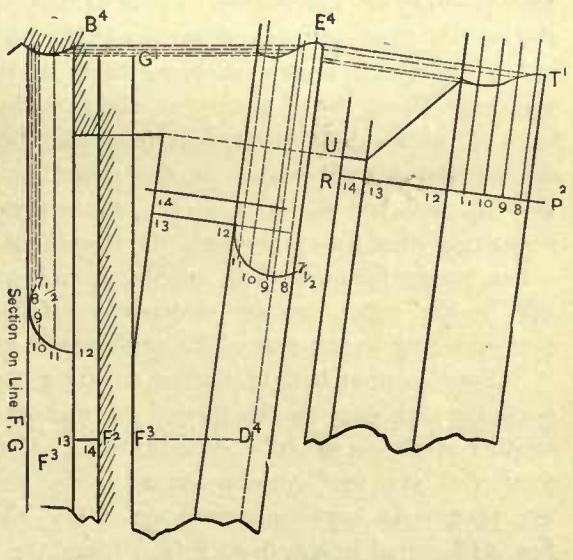


Fig. 417.—True Face of Octagonal Side and Part of Pattern.

Patterns for a Hip Molding Mitering Against the Bed Molding of a Deck Cornice on a Mansard Roof which is Square at the Base and Octagonal at the Top.

profile of the plan on to the miter line E, and thence carried downward and intersected with horizontal lines from the corresponding points of the bed molding in section, also shown at E^2, thus giving the appearance of the miter between the two arms of the bed mold behind their intersection with the hip roll. The vertical lines from the miter E of the plan have not been carried, in the engraving, further than E^1, where they are intersected with lines from corresponding points from the profile at B of the elevation, thus showing how the operation is performed. This has been done to avoid a confusion of lines at E^2. Having obtained this line in the true face, the point where it crosses the miter line between the hip mold and bed mold previously obtained at E^2 must be noted. A line from this point of intersection must then be carried parallel to the line of the molding in the true face, back to the profile of the hip, and there marked, as shown by the figure $7\frac{1}{2}$. The position of the point $7\frac{1}{2}$ should now be marked upon the section of the hip molding previously obtained at O^1 in Fig. 416. So much of the profile as exists between 1 and $7\frac{1}{2}$ in the true face is used in obtaining the stretchout of this part of the pattern. The remaining portion of the stay—namely, from $7\frac{1}{2}$ to 14—is afterward used for the true face of the octagonal side for the remainder of the pattern.

At right angles to the line of the molding in the true face lay off a stretchout equal to that portion of the profile thus used, as shown by P N, through the points in which draw measuring lines in the usual manner. Place the T-square at right angles to the lines of the molding in the true face, and, bringing it against the several points in the miter line between the hip and bed molding at E^2, cut corresponding measuring lines drawn through the stretchout. Then a line traced through these points, as shown by S T, will be the miter line for that portion of the pattern corresponding to the part of the profile thus used.

For the other half of the hip molding, being that portion which lies on the face of the transition piece, another operation must be gone through. Construct a section of the roof corresponding to the line F G in the plan. At any convenient point lay off F^1 C^1 in Fig. 415, equal in length to F G. From the point C^1 erect a perpendicular, C^1 B^2, in length equal to C B of the section. Connect F^1 and B^3. Then F^1 B^2 is the length of the transition side of the roof through that portion corresponding to F G of the plan. It will be well to add to this at B^3 a section of the bed mold as it appears in the section below, thus establishing the true relation between it and the transition side of the roof. By means of this section and the plan, construct a true face of one-half the transition side of the roof, by means of which to obtain the miter of the remaining portion of the roll. To do this first redraw the section B^2 F^1, placing the line of the roof in a vertical position, as shown by B^4 F^2, Fig. 417, from the points in which project horizontal lines, as shown to the right, upon each of which set off from an assumed vertical line the width of the roof as given in the plan. Thus make G^1 E^4 equal to G E of the plan, and F^2 D^4 equal to F D. Connect D^4 and E^4. Then G^1 E^4 D^4 F^3 is the true face of that portion of the roof represented by G E D F in the plan.

In connection with the vertical section just described place so much of the stay as was not used for the pattern already delineated, and in the elevation of the transitional face of the roof place a corresponding portion of the profile, as shown, each of which divide into the same number of spaces. From the points thus obtained carry lines parallel to the lines of the respective views of the part, those in the vertical section cutting the bed molding, and those in the elevation being produced indefinitely. From the points in the bed molding of the vertical section carry lines horizontally, intersecting those drawn from the profile in the elevation, thus establishing the miter line, as indicated at E^4. At right angles to the line D^4 E^4 set off a stretchout of the profile, as shown by R P^2, through the points in which draw the usual measuring lines. With the T-square placed parallel to this stretchout line, or, what is the same, at right angles to the line D^4 E^4, and being brought successively against the points in the miter line at E^4, cut corresponding measuring lines, as shown. Points also are to be carried across, in the same manner as described, corresponding to the bottom of the apron or fascia strip in connection with the bed molding. Then a line traced through these points, as indicated by the line drawn from U to T^1, will be the pattern of the other half of the hip molding. By joining the two patterns thus obtained upon the dividing line of the stay, corresponding to P T of the first piece or P^2 T^1 of the second piece, the pattern will be contained in one piece.

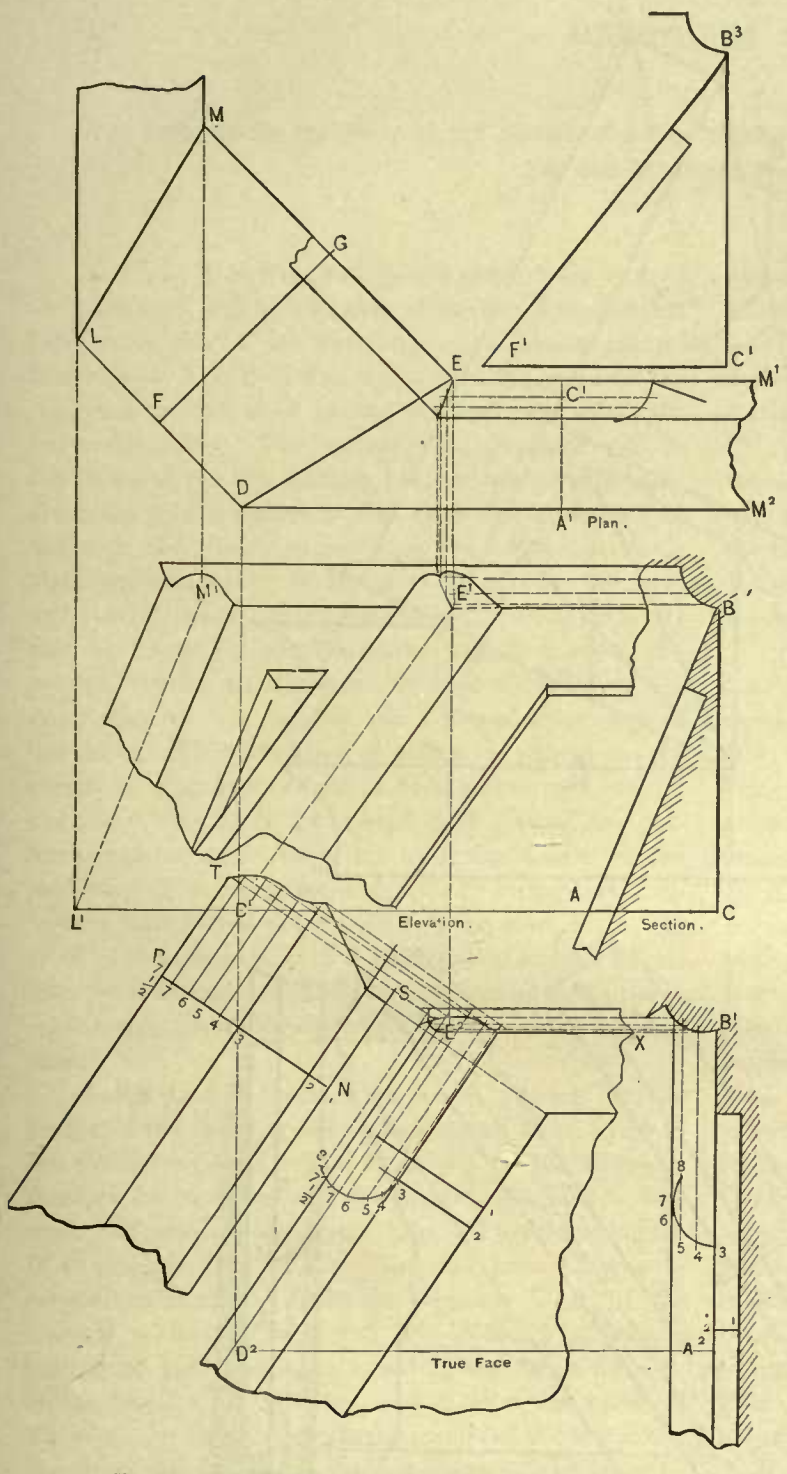


Fig. 415.—Plan, Elevation, True Face and Part of Pattern.

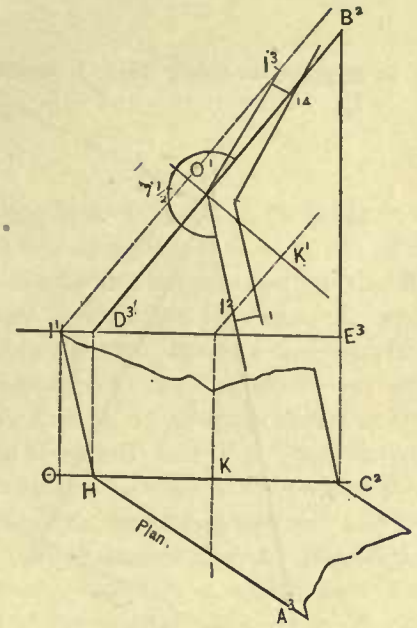


Fig. 416.—Diagonal Section.

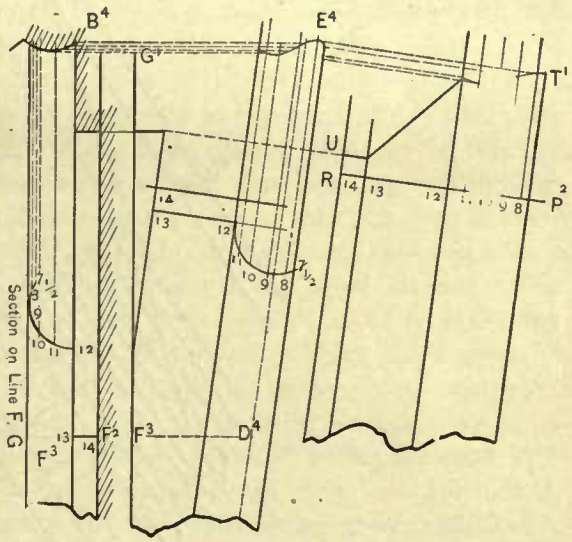


Fig. 417.—True Face of Octagonal Si le and Part of Pattern.

Patterns for a Hip Molding Mitering Against the Bed Molding of a Deck Cornice on a Mansard Roof which is Square at the Base and Octagonal at the Top.

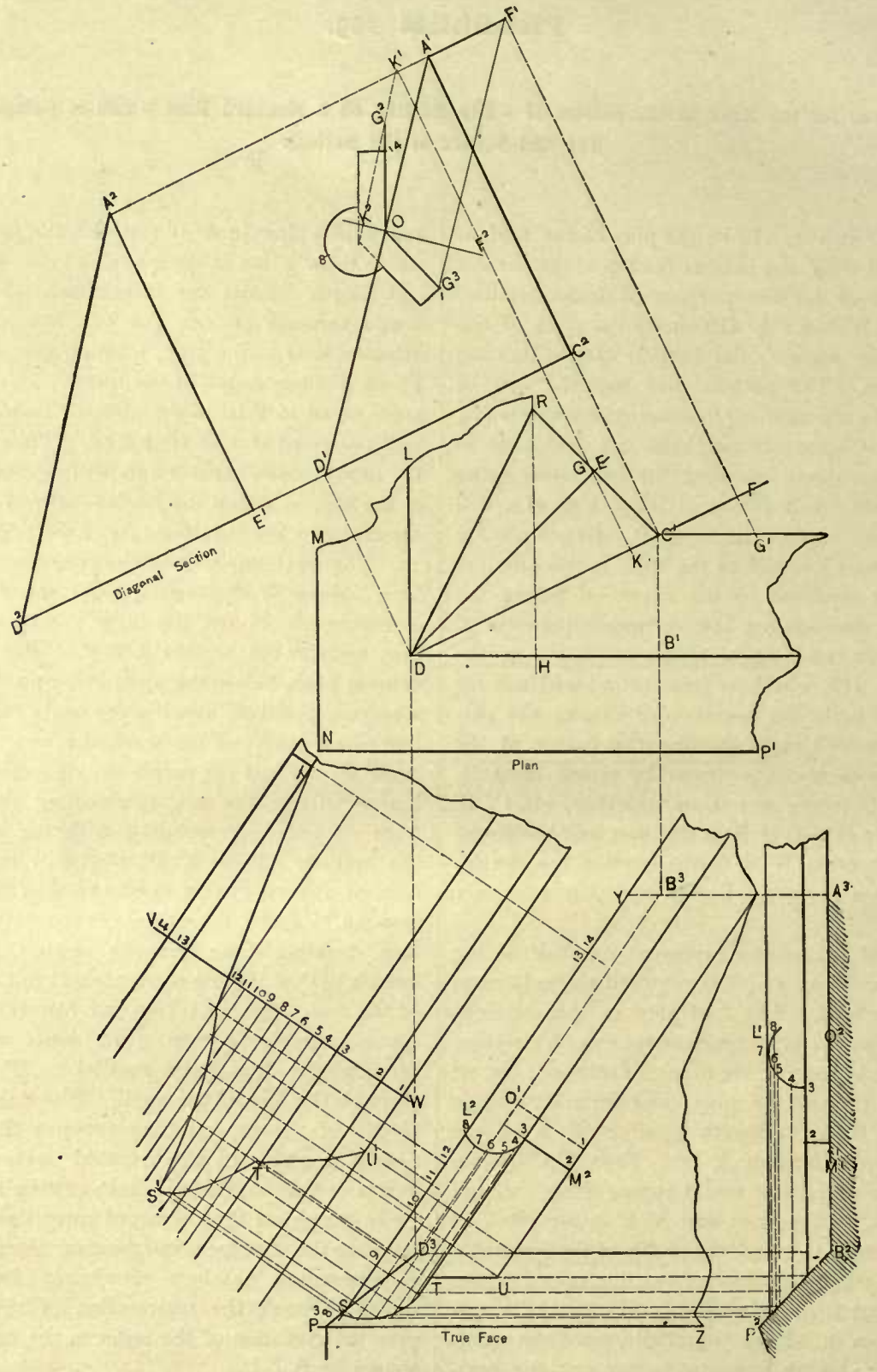


Fig. 418.—The Patterns for the Miter at the Bottom of a Hip Molding on a Mansard Roof Which is Octagon at the Top and Square at the Bottom.

correspond to the point 8. Locate the point 8 on the first section of the hip obtained near O, as shown, and use the remainder of profile 8 to 14 for another operation. Lay off a stretchout of the entire profile of the hip molding, as shown by W V, through the points in which draw the usual measuring lines. With the T-square placed at right angles to the lines of the hip, as shown in the true face, and brought against the points in the miter line S T U, cut so many of the measuring lines drawn through the stretchout W V as correspond to those points. By this means that portion of the pattern shown by S' T' U' will be obtained.

For the portion of the pattern corresponding to the part of the profile which miters against the other hip mold it will be necessary first to construct a true face of the octagon side of the roof. To do this, obtain a diagonal section of the roof corresponding to the line D E in the plan, viz.: Lay off D^2 E' equal to D E of the plan, and from E' erect a perpendicular, E' A^2, equal to C A of the section in Fig. 419. Connect A^2 and D^2. Then A^2 D^2 is the length of the diagonal face of the roof measured on the line D E of the plan. Upon any convenient straight line lay off D^4 A^4 in Fig. 420, in length equal to D^2 A^2, and from A^4 set off, at right angles to it, A^4 C^3, in length equal to E C' of the plan. Then D^4 A^4 C^3 shows in the flat one-half of the diagonal face of the roof, or what is represented by D E C' in the plan. At right angles to D^4 C^3 draw the remaining portion of the stay not used in connection with the true face, placing it in such a manner that the point O^3, corresponding to O of the hip section, shall fall upon the line D^4 C^3, which represents the angle of the hip. Through the point 8 of the section L^5 M^7, corresponding to 8 of the section L^2 M^2 of Fig. 418, draw a line parallel to D^4 C^3, as shown by S^2 Y'. Then S^2 Y' corresponds to S Y of the true face in Fig. 418.

Space the profile L^5 M^7 into the same parts as used in laying off the stretchout W V, and through the points draw lines parallel to D^4 C^3, cutting the line S^2 A^4, which, being the center line of the octagonal side of the roof, is also the miter line between the two arms of the hip molding. From the points of intersection in the line D^4 A^4, at right angles to S^2 Y', draw lines cutting S^2 Y', giving the points marked 8, 9, 10, 11, 12, 13 and 14. For convenience in using one stretchout for the entire pattern, transfer these points to the line S Y of the true face in Fig. 418, from which, at right angles to S Y, draw lines cutting the corresponding measuring lines of the stretchout. Then a line traced through these points of intersection, as shown from S' to X, will complete the pattern.

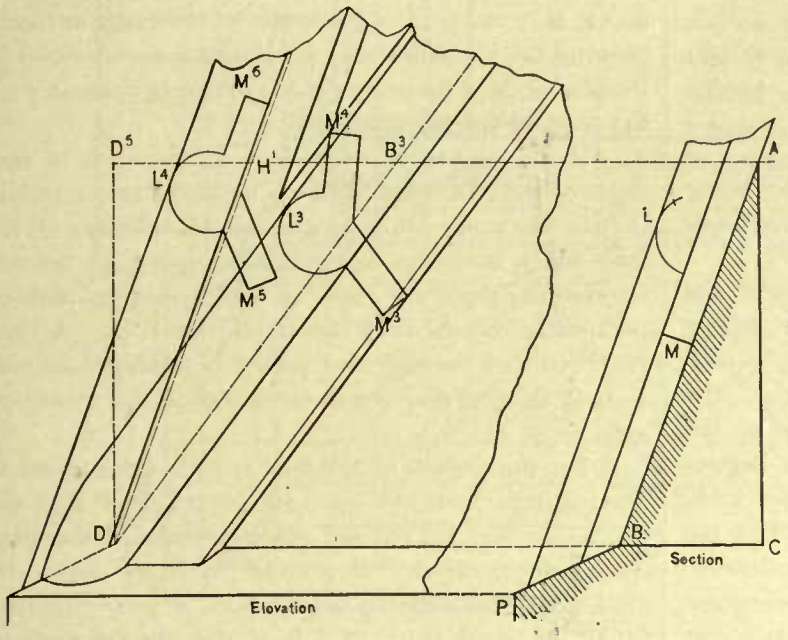


Fig. 419.—Section and Elevation of the Miter at the Bottom of a Hip Molding on a Mansard Roof Which is Octagon at the Top and Square at the Bottom.

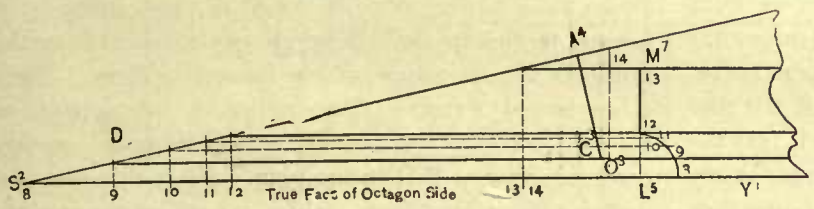


Fig. 420.—Miter between the Inner Edges of the Hip Moldings at the Bottom.

PROBLEM 110.

Patterns for the Fascias of a Hip Molding Finishing a Curved Mansard Roof which is Square at the Base and Octagonal at the Top.

The conditions involved in this problem do not differ greatly from those given in Problems 80, 81 and 82, near which it should properly be classed. In this case, however, the profile of an entire roof is under consideration instead of that of a simple molding or vase, but the problem is here introduced as being closely related in feature to several of the foregoing problems.

C D E F of Fig. 421 represents the plan of the roof at its base, while V G H W represents the plan at the top. It will be seen that the roof is nearly square at the foot of the rafters and octagonal at the top. The same conditions may arise where the corners of the roof are chamfered, starting at nothing at the bottom and increasing to a considerable space at the top, without reference to forming an octagon. D G H E in the plan represents a chamfer or transition piece in the construction of a roof which, as above described, is square at the base and octagonal at the top. This part is represented in elevation by D^2 G^2 H^2 E^2. The elevation is introduced here not for any use in pattern cutting, but simply to show the relation of parts. In the sectional view of the roof O A B the outer line O B represents the surface of the fascias of which the patterns are required, the inner curve showing the line of the roof boards and the depth of the sink strips. As it is in the plan that the miter lines are shown it will be necessary to develop the pattern from the plan. Assuming then that one of the square sides, as E F W H, is to be done first, it will be necessary to place a profile so that its projection O A shall lie across this part of the roof, as shown by O^1 A^1 B^1.

Divide the profile O^1 B^1 into any convenient number of equal spaces, and from the points of division drop lines parallel to E F, the side of the roof, cutting the miter line E H. Upon any line at right angles to this side of the roof, as O^2 B^4, lay off a stretchout through the points, in which draw the usual measuring lines. Cut these measuring lines by lines drawn vertically from the points in E H. Then a line traced through these points of intersection, as shown by E^2 H^2, will be the line of the pattern corresponding to the line E H in the plan. The width of the flange or fascia forming the hip finish may be obtained as described in Problem 6, and the corner piece drawn in to agree with the original design, as shown by S^1 T^1

If it is desirable to produce an elevation of this angle of the roof it can be done by dividing the profile O B by the same points as were used in dividing O^1 B^1, from which horizontal lines can be drawn to the left intersecting with the lines of corresponding number previously erected from the miter line E H. A line, E^2 H^2, drawn through the points of intersection will with D^2 G^2 give the correct elevation of the transition side.

For the pattern of this side it will be necessary to first construct a section upon its center line, P R of the plan. At any convenient place outside of the plan draw a duplicate of P R parallel to it, as shown by P^1 A^1, and from the point A^1 erect a perpendicular, A^1 B^1, in length equal to A B of the original section. In A^1 B^1 set off points corresponding to the points in A B, and through them draw horizontal lines, as shown. Place the T-square parallel to A^1 B^1, and, bringing it against the points in E H previously obtained from the profile O^1 B^1, cut corresponding measuring lines. Then a line traced through these points of intersection, as shown by B^1 P^1, will complete the diagonal section corresponding to P R in the plan. From this diagonal section take a stretchout, which lay off on the straight line corresponding to P R produced, all as shown by P^2 B^3. Through the points in P^2 B^3 draw the usual measuring lines. With the T-square placed parallel to this stretchout line, and brought successively against the points in E H, cut the measuring lines, as shown. Then a line traced through these points of intersection, as shown by E^1 to H^1, will be one side of the required pattern. In like manner, having transferred points from E H across to the corresponding line D G, cut the measuring lines from it, which will give the other side of the required pattern. The width of fascias (whose intersection forms a panel in this case) may be obtained as suggested above and as given in Problem 6.

In locating the points N^1 and M^1 of this pattern it

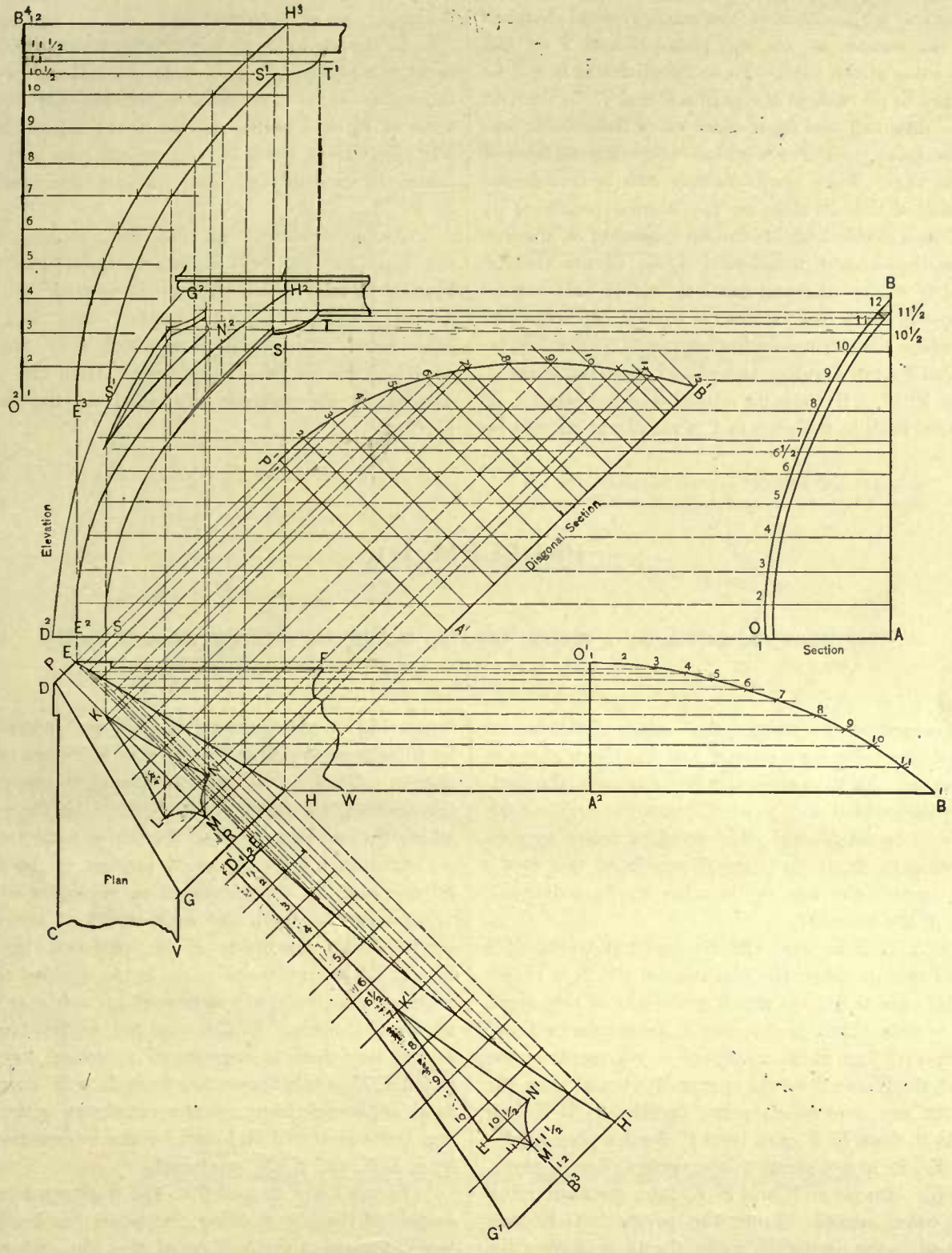


Fig. 421.—Patterns for the Fascias of a Hip Molding Finishing a Curved Mansard Roof Which is Square at the Eaves and Octagonal at the Top.

is desirable for the sake of design that they be, when finished and in position, at the same vertical distance below the cornice as are the points S and T on the square sides of the roof. To accomplish this it will be necessary to go back to the points S^1 and T^1, in the first pattern obtained, and from them carry lines back into the stretchout line O^2 B^4, where they are numbered $10\frac{1}{2}$ and $11\frac{1}{2}$. Their positions may now be transferred by means of the dividers to the normal profile O B, where their vertical hights can be measured on the line A B, as shown, and transferred again to the vertical line A^1 B^1 of the diagonal section. It is only necessary now to carry them across, as shown, to the profile P^1 B^1, where their distances from adjacent points may be measured by the dividers and placed upon the stretchout line P^2 B^2. By similar means the appearance of this panel both in the plan and in the elevation may be completed if so desired, all of which will be made clear by inspection of the drawing.

In the case of very large roofs, where the development of a profile or a pattern to the full size would be impracticable, it is possible to perform the work to a scale of $1\frac{1}{2}$ or 3 inches to the foot; after which full size patterns of parts of convenient size may be obtained by multiplying their various dimensions by 8 or 4.

As the patterns for the roll, usually finishing the hip, are properly included under the head of Flaring Work, which subject is treated in the following section of this chapter, they will not be given here. The radii from which they can be obtained, however, may be derived from the diagonal section in the manner described in the following problem.

PROBLEM III.

To Obtain the Curves for a Molding Covering the Hip of a Curved Mansard Roof.

The method of obtaining the pattern of the fascias of a molding covering a curved hip has been given in Problem 6. As it is necessary in obtaining the patterns of the molded portion or roll, that the curve of the hip should be established, this problem really consists of developing from the normal profile of the roof a profile through the hip, or, in other words, a diagonal section of the mansard.

Let A E B in Fig. 422 represent the plan of a mansard roof or tower, the elevation of which is shown by H K, over the hip of which a molding of any given profile is to be fitted, in this case a three-quarter bead, the diagonal line E F in the plan representing the angle of the hip as it would appear if viewed from the top. At any convenient point parallel to E F, and equal to it, draw E^1 F^1, and from F^1 erect a perpendicular, F^1 K^1, in length equal to the vertical line in elevation G K. Divide G K and F^1 K^1 into the same number of equal spaces. From the points in G K draw lines cutting the profile H K, as shown, and from the points thus obtained in H K drop lines vertically, producing them until they cut the diagonal line E F of the plan, as shown. Through the points in F^1 K^1 draw measuring lines in the usual manner, and intersect them by lines erected perpendicularly to E F from the points therein. Then a line traced through these points of intersection, as shown by E^1 K^1, will be the profile to which the molding covering the hip is to be raised.

Inasmuch as in the usual process of mold raising all curves must be considered as segments of circles, to accommodate both the adjustment of the machine used and the describing of the patterns, the curved line E^1 K^1 just obtained must be so divided that each section or segment will approach as nearly as possible an arc of a circle. In this case the section from E^1 to L will be found to correspond to an arc struck from a center, M, while the section from L to K^1 corresponds to an arc struck from a center not shown in the engraving, but which will be found by the intersection of the lines L N and K^1 N^1 produced.

In the lower part of Fig. 423 is shown an enlarged section of the hip molding, including the fascias, as it would appear at the bottom of the hip, and above it another section taken at the top, which has been derived from the normal section or section at the bottom by the method used and explained in Problems 105,

106 and 107, previously demonstrated. A dotted reproduction of the lines of the upper section is placed here to show the change in the flare that takes place between fascias in going from the bottom to the top of the hip, thus showing that the outer edges of the roll require trimming after being raised so that the roll may have an equal projection throughout its course.

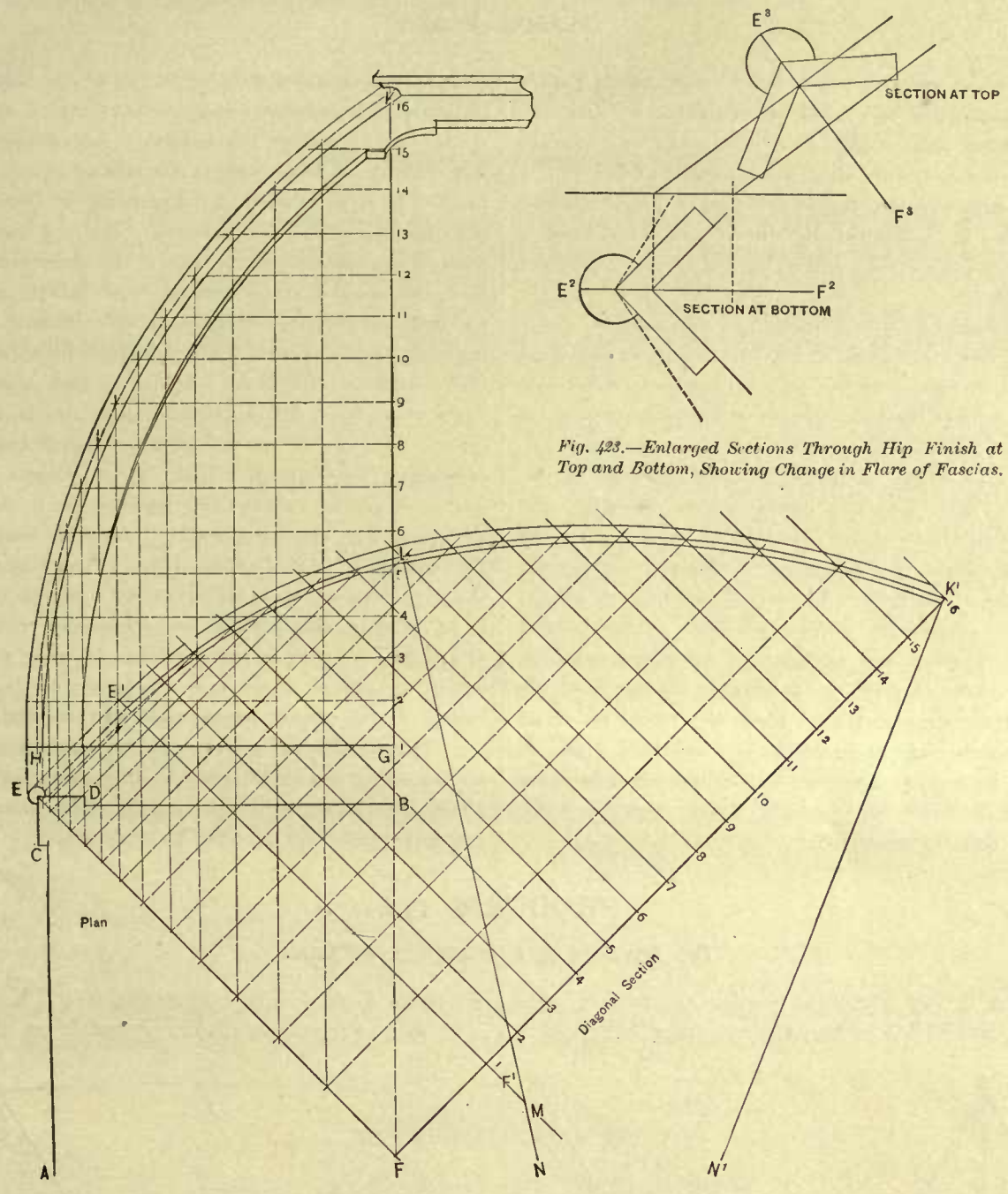


Fig. 423.—Enlarged Sections Through Hip Finish at Top and Bottom, Showing Change in Flare of Fascias.

Fig. 422.—Diagonal Section of a Curved Mansard Roof Obtained for the Purpose of Mold Raising.

Methods of obtaining the patterns of curved moldings will be found in the following section of this chapter.

SECTION 2.

Regular Tapering Forms.

(FLARING WORK.)

It will be well to place before the reader here a clear statement of the class of problems he may expect to meet with under this head. It will include only the envelopes of such solid figures as have for a base the circle, or any figure of equal or unequal sides which may be inscribed within a circle, and which terminate in an apex located directly over the center of the base.

According to the definition of an inscribed polygon (Def. 66), its angles must all lie in the circumference of the same circle. So the angles or hips of a pyramid whose base can be inscribed in a circle must lie in the surface of a cone whose base circumscribes its base and whose altitude is equal to that of the pyramid. Therefore the circle which describes the pattern of the base of the envelope of such a cone will also circumscribe the pattern of the base of the pyramid contained within it. The envelopes of such solids, therefore, as scalene cones, scalene pyramids and pyramids whose bases cannot be inscribed within a circle are not adapted to treatment by the methods employed in this section. Even the envelope of an elliptical cone cannot be included with this class of problems because it possesses no circular section upon which its circumference at any fixed distance from the apex can be measured.

In this connection it is proper to call attention to the difference between a scalene cone and a right cone whose base is oblique to its axis. According to Definition 96, a scalene cone is one whose axis is inclined to the plane of its base, and according to Definition 94 the base of a cone is a circle. As any section of a cone taken parallel to its base is the same shape as its base, any section of a scalene cone taken parallel to its base must be a circle, and any section taken at right angles to its axis could not, therefore, be a circle, but would be elliptical. Again, as any section of a right cone (Def. 95) at right angles to its axis is a circle, if its base be cut off obliquely, such base would, according to Definition 113, be an ellipse. Therefore, since its horizontal section is a circle, its envelope may be obtained by methods employed in this section. (See Problem 136.) And since the section of a scalene cone taken at right angles to its axis is an ellipse, the scalene cone becomes virtually an elliptical cone with an oblique base—that is, with a base cut off at such an angle as to produce a circle—and, as stated above, cannot be included in this section.

The principles governing the problems of this section are given in Chapter V, beginning on page 79, which the reader will find a great help in explaining anything which he may fail to understand.

PROBLEM 112.

The Envelope of a Triangular Pyramid.

Let A B C of Fig. 424 be the elevation of the pyramid, and E F G of Fig. 425 the plan. From the center K draw the lines E K, F K and G K in the plan, representing the angles or hips of the pyramid. From the point K erect K H, perpendicular to F K and equal in length to the hight of the pyramid, as shown by A D of the elevation. Draw the hypothenuse F H, which then represents the length of the corner lines.

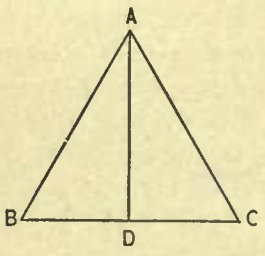


Fig. 424.—Elevation.

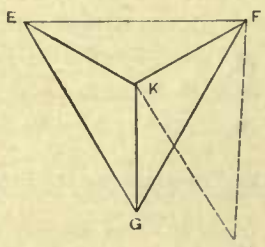


Fig. 425.—Plan.

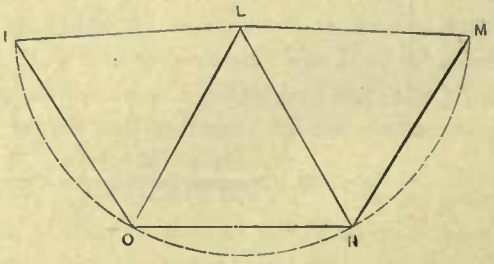


Fig. 426.—Pattern.

The Envelope of a Triangular Pyramid.

From any point, as L of Fig. 426, for center, with radius equal to F H, describe the arc M N O I indefinitely, and draw L M. From M set off the chord M N, in length equal to the side F G of the plan. In like manner set off N O and O I respectively, equal to G E and E F of the plan. Connect I and L, as shown, and draw L O and L N. Then L I O N M is the pattern sought.

PROBLEM 113.

The Envelope of a Square Pyramid.

Let E A C of Fig. 427 be the elevation of the pyramid, and F H K L of Fig. 428 the plan. The diagonal lines F K and L H represent the plan of the angles or hips, and G a point corresponding to the apex A of the elevation. From the apex A drop the line A B perpendicular to the base E C. Prolong E C in the direction of D, making B D equal to G F, one of the angles of the plan. Connect D and A. Then A D will be the slant hight of the article on one of the corners, and the radius of an arc which will contain or circumscribe the pattern, as shown in the diagram From any center, as M, Fig. 429, with a radius equal to A D, describe an arc, as P R O S N, indefinitely and draw M P. From P, on the arc drawn, set off a chord, P R, in length equal to one of the sides of the pyramid shown in the plan. From R set off another chord, R O, in like manner, and repeat the same operation, obtaining O S and S N. Draw the lines M N, M S, M O and M R. Then M N S O R P will be the required pattern.

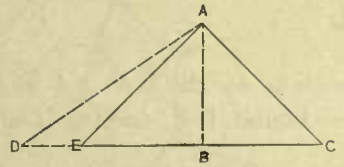


Fig. 427.—Elevation.

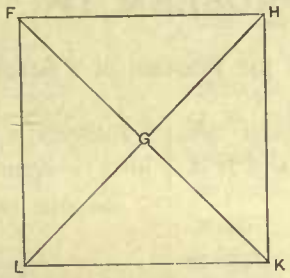


Fig. 428.—Plan.

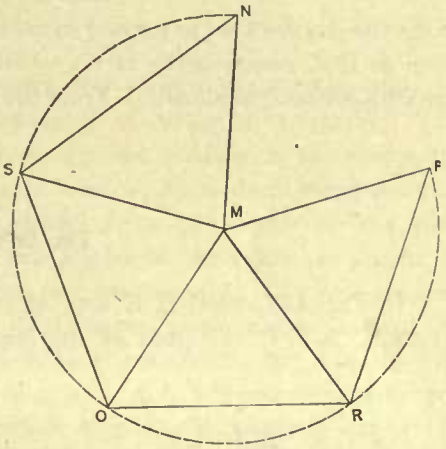


Fig. 429.—Pattern.

The Envelope of a Square Pyramid.

PROBLEM 114.

The Envelope of a Hexagonal Pyramid.

Let H G I of Fig. 430 represent the elevation of a hexagonal pyramid, of which D F C L B E of Fig. 431 is the plan. The first step is to construct a section on a line drawn from the center of the figure through one of its angles in the plan, as A B. From the center A erect A X perpendicular to A B, making it equal to the straight hight of the article, as shown in the elevation by G K. Draw the hypothenuse B X. Then X represents the apex and X B the side of a right cone, the plan of the base of which, if drawn, would circumscribe the plan of the hexagonal pyramid. From any convenient center, as X' of Fig. 432, with X B of

Fig. 431 as radius, describe an arc indefinitely, as shown by the dotted line. Through one extremity of the arc to the center draw a line, as shown by D' X'. B' L' in the arc thus obtained draw lines to the center, as shown by E' X', B' X', etc., which will represent the angles of the completed shape, and serve to locate

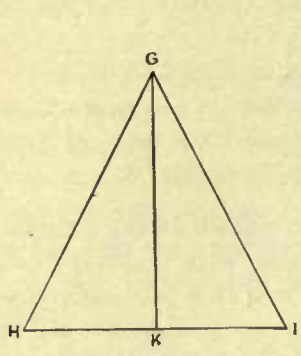


Fig. 430.—Elevation.

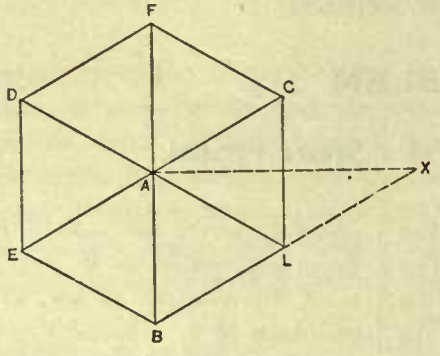


Fig. 431.—Plan.

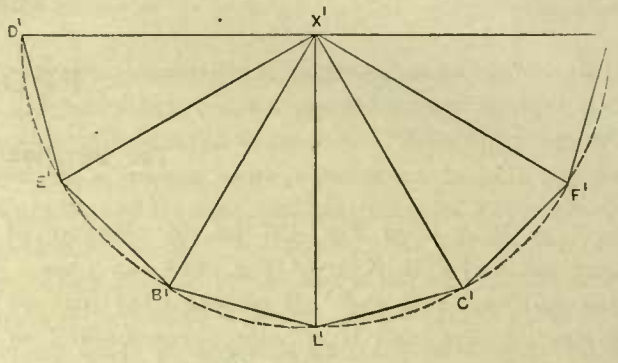


Fig. 432.—Pattern.

The Envelope of a Hexagonal Pyramid.

With the dividers set to a space equal to any side of the plan, as D E, commencing at D', set off this distance on the arc six times, as shown. From the several points E' the bends to be made in process of forming up. Then X' D' E' B' L' C' F' D² will be the complete pattern.

PROBLEM 115.

The Envelope of the Frustum of a Square Pyramid.

In Fig. 433, let G H K I be the elevation of the article, C A E D the plan of the larger end and L M O N the plan of the smaller end. Produce the hip lines C L, A M, etc., in the plan to the center P. Construct a diagonal section on the line A P as follows: Erect the perpendicular P F, making it equal to the straight hight of the article, as shown by R K of the elevation. Likewise erect the perpendicular

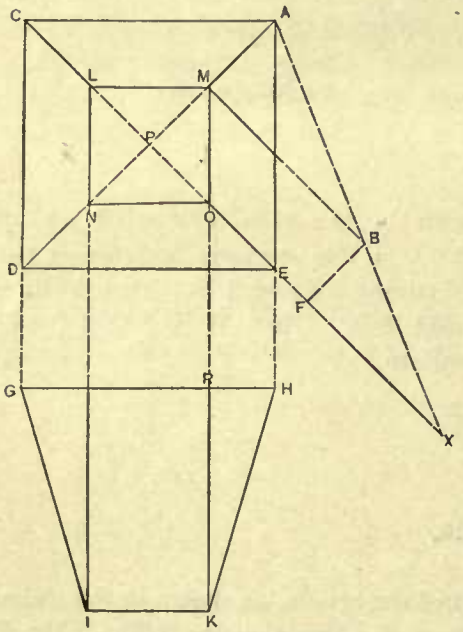


Fig. 433.—Plan and Elevation.

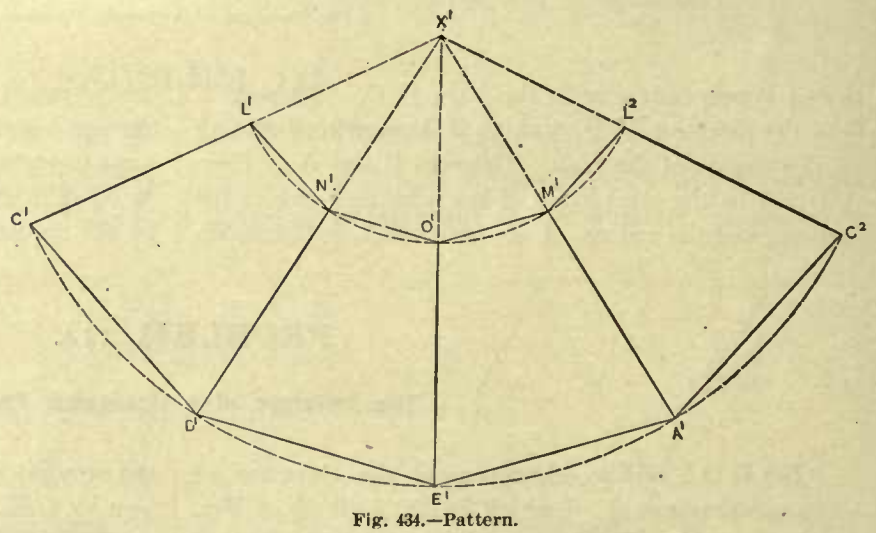


Fig. 434.—Pattern.

The Envelope of the Frustum of a Square Pyramid.

M B of the same length. Draw F B and A B. Then P A B F is the diagonal section of the article upon the line P A. Produce A B indefinitely in the direction of X, and also produce P F until it meets A B extended in the point X. Then X is the apex of a right cone and X A the side of the same, the base of which, if drawn, would circumscribe the plan C A E D. Therefore, from any convenient center, as X' of Fig. 434, with X A as radius, describe the arc C' D' E' A' C², and from the same center, with radius X B, draw the arc L' N' O' M' L², both indefinitely. Draw C' X', cutting the smaller arc in the point L'. Make the chord C' D' equal in length to one side, C D, of the plan, and D' E' to another side, D E, of the plan, and so on, until the four sides of the base have been set off. Draw D' X', E' X', etc., cutting the arc L' L² in the points N', O', etc. Then D' N', E' O' and A' M' will represent the lines of the bends in forming up the pattern. Draw the chords L' N', N' O', etc., thus completing the pattern.

PROBLEM 116.

The Envelope of the Frustum of an Octagonal Pyramid.

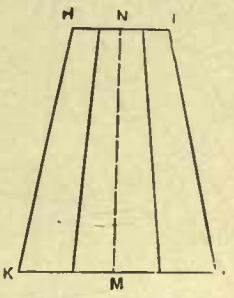


Fig. 435.—Elevation.

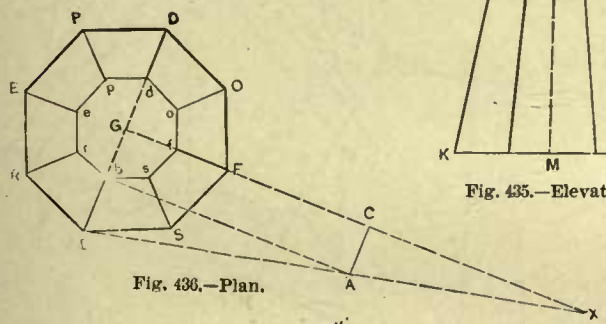


Fig. 436.—Plan.

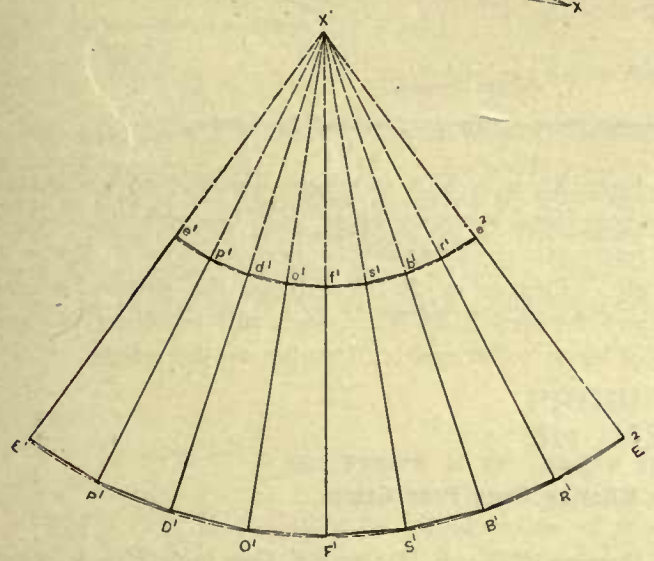


Fig. 437.—Pattern.

The Envelope of the Frustum of an Octagonal Pyramid.

Fig. 435 shows the elevation and Fig. 436 the plan of the frustum of an octagonal pyramid. The first step in developing the pattern is to construct a diagonal section, the base of which shall correspond to one of the lines drawn from the center of the plan through one of the angles of the figure, as shown by G. B. Erect the perpendicular G C equal to the straight hight of the frustum, as shown by N M of the elevation, and at *b* erect a perpendicular, *b* A, of like length. Draw B A and A C. Then G B A C is a section of the article as it would appear if cut on the line G B. Produce B A indefinitely in the direction of X, and likewise prolong G C until it intersects B A produced in X. Then X is the apex and X B the side of a right cone, the plan of which, if drawn, would circumscribe the base of the frustum. From any convenient center, as X', Fig. 437, with radius X B, describe an arc indefinitely, as shown by the dotted line E' E² of the pattern, and from the same center, with X A for radius, describe the arc $e^1\ e^2$ of the pattern. Through one extremity of the arc E' E₂ to the center draw a straight line, as shown by E' X', cutting the smaller arc in the point e^1. Set off on the arc E' E² spaces equal to the sides of the plan of the base of the article and connect the points by chords. Thus make E' P' of the pattern equal to E P of the plan, and so on. Also from these points in the arc draw lines to the center, cutting the arc $e^1\ e^2$, as shown. Connect the points thus obtained in this arc by chords, as shown by $e^1\ p^1$, $p^1\ d^1$, $d^1\ o^1$, etc. Then e^1 E' E² e^2 will be the pattern sought.

PROBLEM 117

The Envelope of the Frustum of an Octagonal Pyramid Having Alternate Long and Short Sides.

In Fig. 438, let I M B N O P K L be the plan of the article of which G H F E is the elevation. The first thing to do in describing the pattern is to construct a section corresponding to a line drawn from the center to one of the angles in the plan, as S B. At S erect the perpendicular S R, in length equal to the straight hight of the article, as shown by C D of the elevation. Upon the point *b* erect a corresponding perpendicular, as shown by *b* A. Draw R A and A B. Then B A R S is a section of the article taken upon the line S B. Produce S R and B A until they meet in the point X. Then X is the apex and X B is the side of a cone, the base of which, if drawn, would circumscribe the plan of the article. From any convenient center, as X', Fig. 439, with radius equal to X B, describe an arc, as shown by M' M². Draw X' M' as one side of the pattern. Then, starting from M', set off chords to the arc, as shown by M' B', B' N', etc., equal to and corresponding with the several sides of the article, as shown by M B, B N, etc., in the plan. From these points, B', N', etc., in the arc, draw lines to the center X'. From X', with X A as radius, describe an arc cutting these lines, as shown by m' m^2. Connect the points of intersection by straight lines, as shown by $m'b'$, $b'n'$, $n'o'$, etc. Then m' m^2 M² M' will be the pattern sought, and the lines B' b', N' n', etc., will represent the lines of bends to be made in forming up the article.

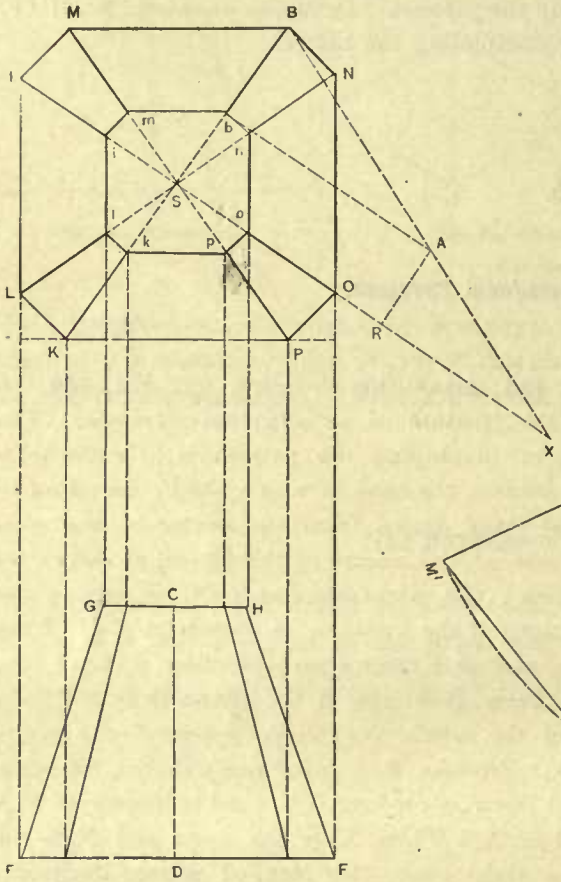


Fig. 438.—Plan and Elevation.

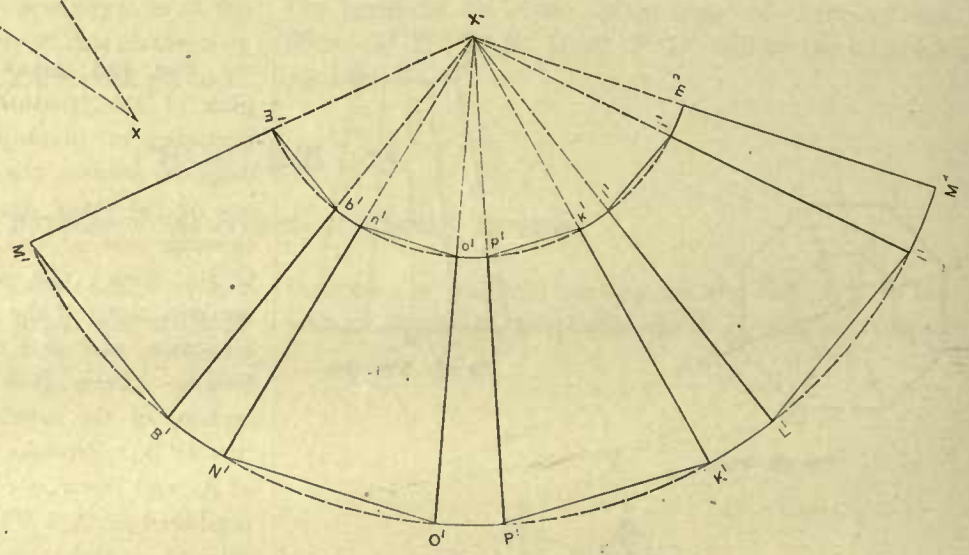


Fig. 439.—Pattern.

The Envelope of the Frustum of an Octagonal Pyramid Having Alternate Long and Short Sides.

PROBLEM 118.

The Pattern of a Square Spire Mitering Upon Four Gables.

In Fig. 440, let B F H C be the elevation of a square spire which is required to miter over four equal gables in a pinnacle, the plan of which is also square. Produce F B and H C until they meet in A, which will be the apex of the pyramid of which the spire is a section. Draw the axis A G, and at right angles to it,

from the lowest point of contact between the spire and the gable, as F, draw F G. Then F G will represent the half width of one of the sides of the pyramid at the base, and A F will represent the length of a side through its center. From any convenient point, as A^1 spaces of the extent of $G^1 G^2$, as shown by $G^2 g$, $g g^1$ and g^2 O. Draw $g^1 A^1$, $g A^1$ and O A^1. Make $A^1 B^1$ equal to A B of the elevation, and through B^1 draw a perpendicular to $A^1 F^1$, as shown. Draw lines corresponding to it through the other sections of the pattern. Make $A^1 D^1$

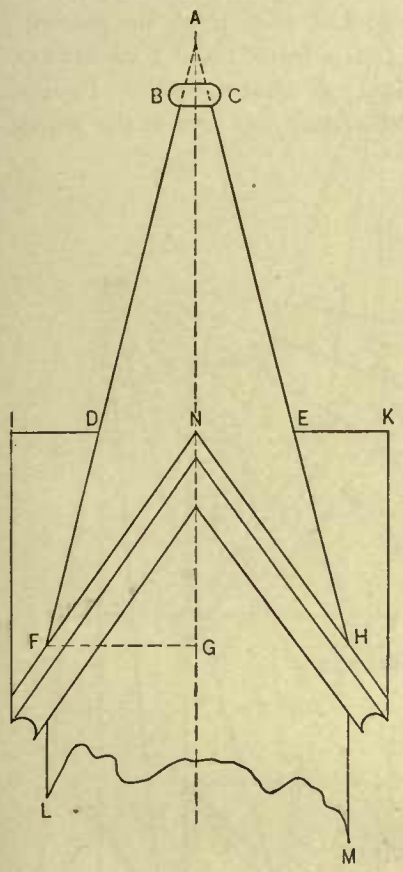


Fig. 440.—Elevation of Spire.

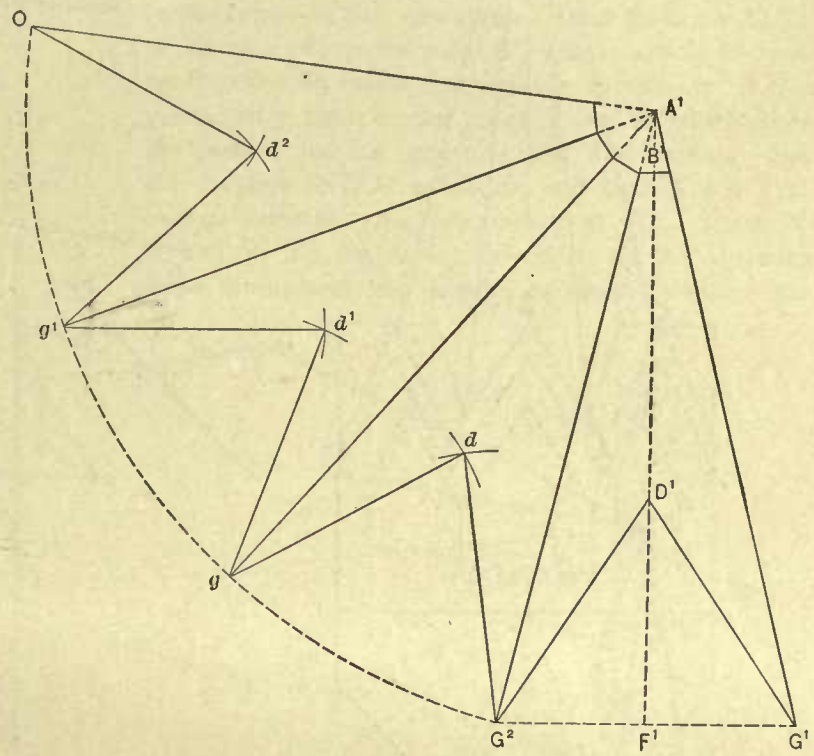


Fig. 441.—Pattern.

The Pattern of a Square Spire Mitering Upon Four Gables.

in Fig. 441, draw $A^1 F^1$, in length equal to A F. From F^1 set off, perpendicular to $A^1 F^1$, on each side a space equal to F G of the elevation, as shown by $F^1 G^1$ and $F^1 G^2$. From G^1 and G^2 draw lines to A^1, as shown. From A^1 as center, and with $A^1 G^2$ as radius, describe an arc, as shown by G^2 O, in length equal to three equal to A D, and draw $D^1 G^1$ and $D^1 G^2$. Set the compasses to G^2 D^1, and from G^2 and g as centers describe arcs interscecting at d. Draw $d g$ and $d G^2$, as shown. Repeat the same operation in the other sections of the pattern, thus completing the required shape.

PROBLEM 119.

The Pattern of an Octagon Spire Mitering Upon Eight Gables.

Let A G L in Fig. 442 be the elevation of the spire, and M O P the half plan. From the point G, which represents the lowest point of the angle or valley between the gables, to H, which represents the meeting of the valleys and ridges at T in the plan, draw the line G H, cutting the side A C extended in the point D. Draw any line, as $A^1 D^1$ in Fig. 443, upon which to construct the pattern. Make $A^1 C^1$ equal to

A C of the elevation, and A' D' equal to A D of the elevation. Through D' draw the horizontal line 1 0, as shown. From D' set off D' 0, equal to E F of the elevation, and likewise set off D' 1, of the same length.

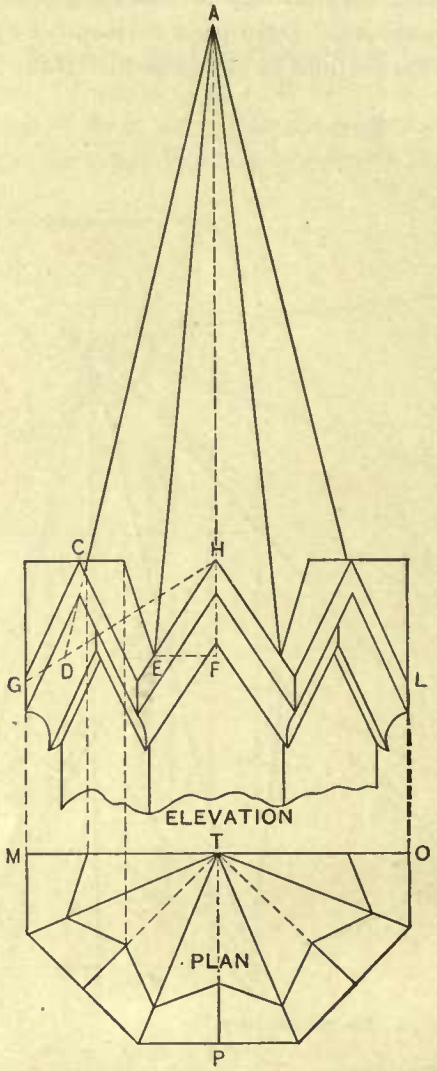


Fig. 442.—Plan and Elevation of Spire.

Draw A' 0 and A' 1. Set the dividers to A' 1 as radius, and from A' as center describe the arc 1 8 indefinitely. Set the dividers to 1 0, and step off as many spaces on the arc as there are sides in the spire. Draw the lines A' 2, A' 3, etc., to A' 8, which represent the angles of the spire and the bends in the pattern. Draw C' 0 and C' 1 in the first section of the pattern. Set the dividers to C' 1, and from 1 and 2 as centers describe intersecting ares, as shown by C^2. In like manner describe similar intersecting ares at the points C^2, C^4, etc. Draw lines from these points to the points 1, 2, 3, 4, etc., as shown, thus completing the pattern.

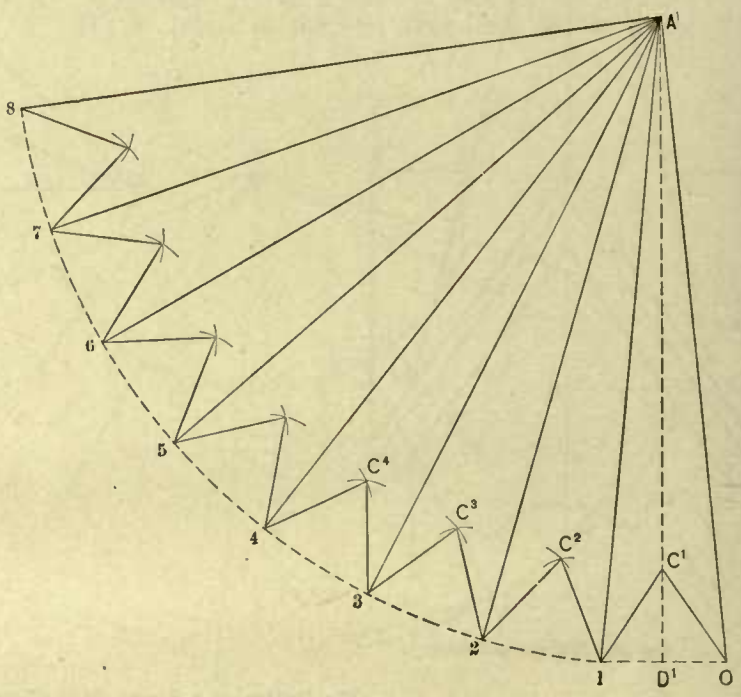


Fig. 443.—Pattern.

The Pattern of an Octagon Spire Mitering Upon Eight Gables.

PROBLEM 120.

The Pattern of an Octagon Spire Mitering Upon Four Gables.

In Fig. 444, let B E Z U be the elevation of an octagon spire, mitering down upon four gables occurring upon a square pinnacle. Continue the side lines until they intersect in the apex A. Draw the center line A H, and from the point G draw G H perpendicular to the center line, showing half the width of one of the sides at the point G. By inspection of the elevation it will be seen that one-half the sides will be notched at the bottom to fit over the gables, while the others will be pointed to reach down into the angles or valleys between the gables.

To ascertain the correct length upon the center line of one of the pointed sides it will be necessary to construct a section through one of the valleys, for in-

stance, upon the line M' N' of the plan. Through the point J of the elevation draw the line J M at right angles to the center line, extending it to the left indefinitely, and from the point M set off upon this line the distance M N, equal to M' N' of the plan. Draw

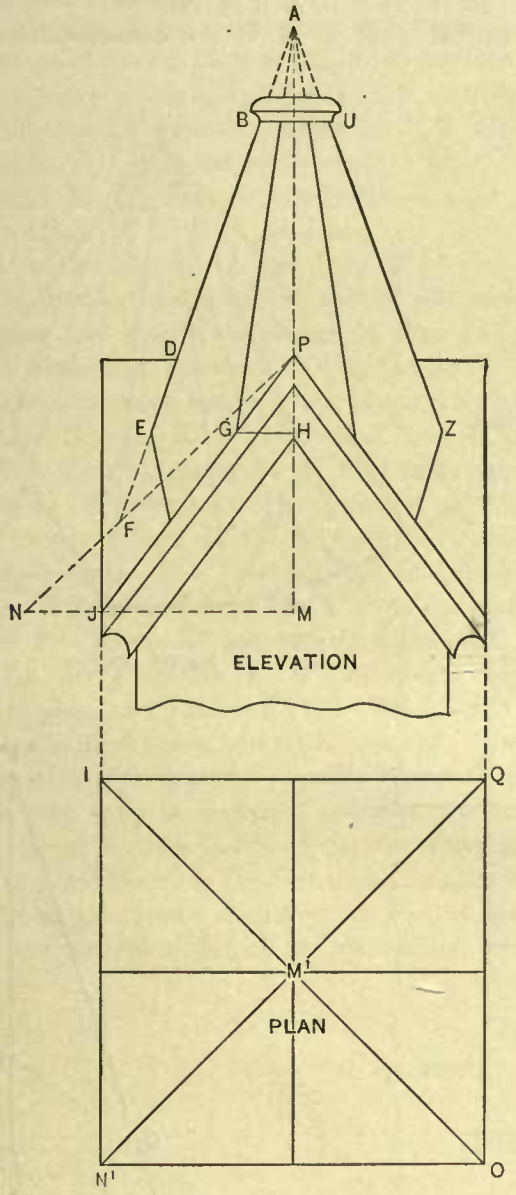


Fig. 444.—Plan and Elevation of Spire.

equal to A E of the elevation, etc. Through E' draw a perpendicular equal in length to the width of a side at the point E, or to twice G H, as shown in the elevation, placing one-half on each side from E', all as shown by L K. From L and K draw lines to A'. From A' as center, with A' L as radius, describe an arc, as shown by L U, indefinite in length. Set the dividers to the space L K, and step off spaces from L, as L Y, Y X, etc., until as many sides are set off as are required in the spire—in this case eight. Draw the lines A' Y, A' X, etc. From the point D', which, as will be seen by D in the elevation, corresponds to the top of the gable, draw lines to the points L and K, which gives the pattern for the notch in the first section. Set the dividers to L D' as radius, and from X and Y as centers describe arcs intersecting at W. Draw W X and W Y, and repeat this upon all the alternate sides throughout the pattern, as shown, locating the

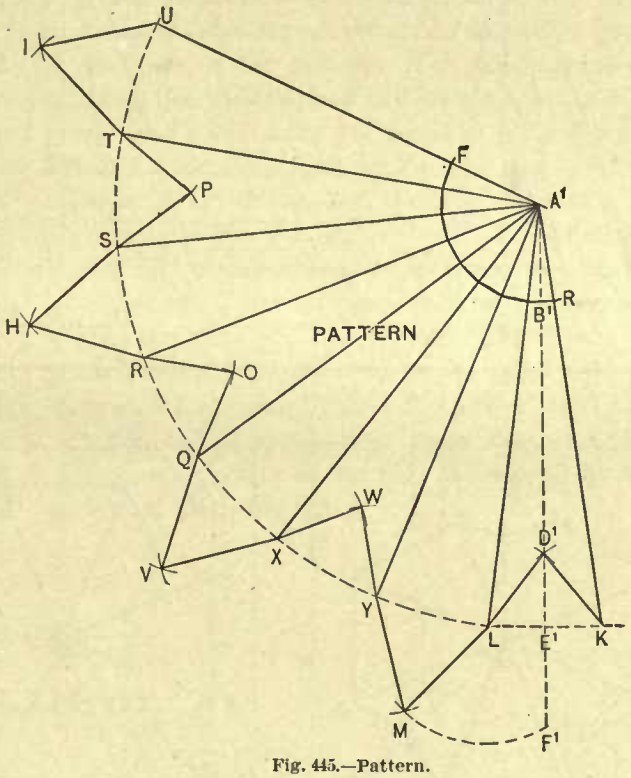


Fig. 445.—Pattern.

The Pattern of an Octagon Spire Mitering Upon Four Gables.

N P, and extend the side A E until it intersects this line at F. Then A F will be the correct length through the center line of one of the long sides.

To describe the pattern first draw A' F' in Fig. 445, equal to A F of the elevation, and set off points on it corresponding to points in A F. Thus make A' B' equal to A B, A' D' equal to A D, and A' E' equal to A E of the elevation, etc. Through E' draw a perpendicular equal in length to the width of a side at the point E, or to twice G H, as shown in the elevation, placing one-half on each side from E', all as shown by L K. From L and K draw lines to A'. From A' as center, with A' L as radius, describe an arc, as shown by L U, indefinite in length. Set the dividers to the space L K, and step off spaces from L, as L Y, Y X, etc., until as many sides are set off as are required in the spire—in this case eight. Draw the lines A' Y, A' X, etc. From the point D', which, as will be seen by D in the elevation, corresponds to the top of the gable, draw lines to the points L and K, which gives the pattern for the notch in the first section. Set the dividers to L D' as radius, and from X and Y as centers describe arcs intersecting at W. Draw W X and W Y, and repeat this upon all the alternate sides throughout the pattern, as shown, locating the points O and P. For the pattern of the point, take a space between the points of the dividers equal to L F', and from L and Y as centers describe small arcs intersecting at M, and draw M L and M Y. With the same radius repeat the operation upon the intermediate sides, establishing the points V, H and I, thus completing the pattern.

PROBLEM 121.

Pattern for an Octagon Spire Mitering upon a Roof at the Junction of the Ridge and Hips.

In Fig. 446, let A B C represent the front elevation of the roof and A′ *a c* C′ the corresponding plan. vation let W O N M K J H represent the octagon spire and H′ J′ K′ M′ N′ O′ the corresponding plan.

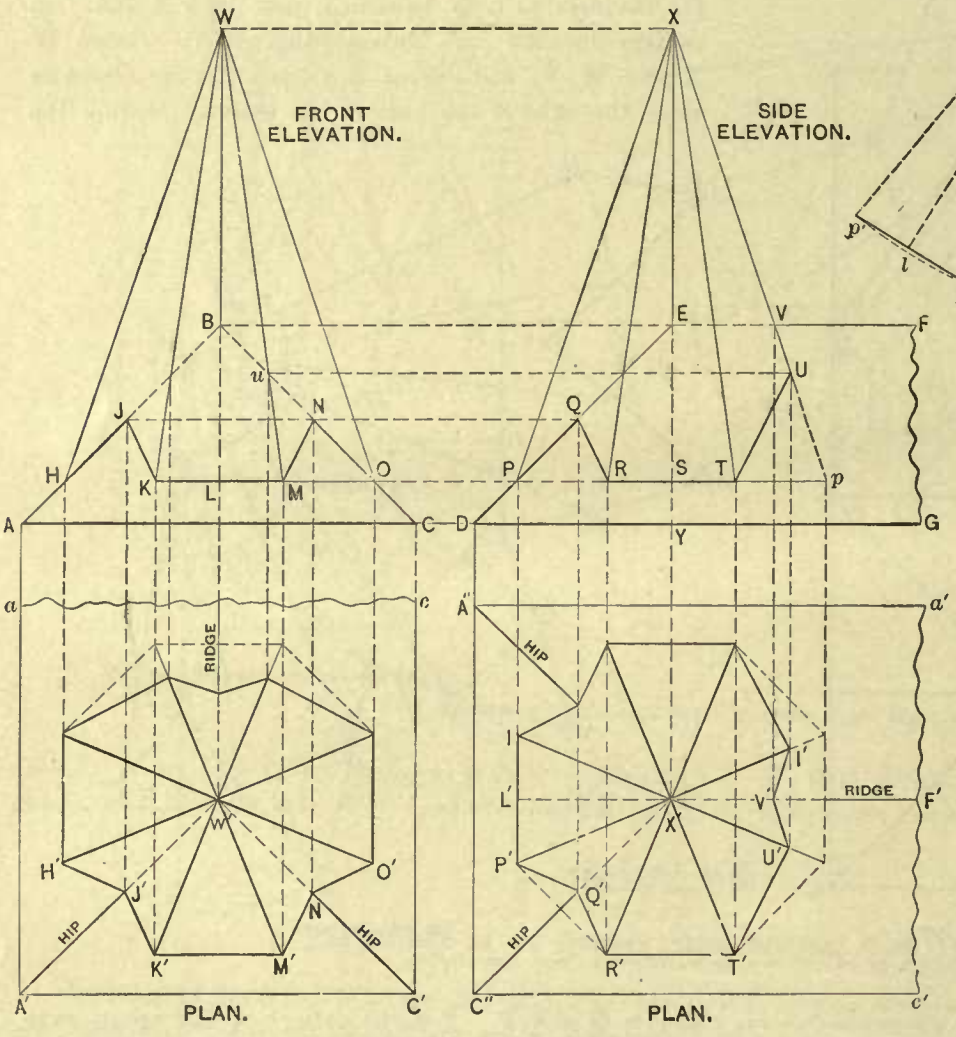


Fig. 446.—Plans and Elevations of Spire.

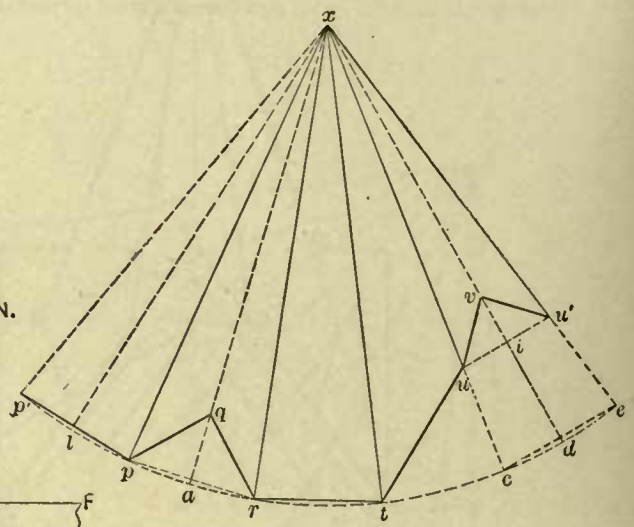


Fig. 448.—Pattern.

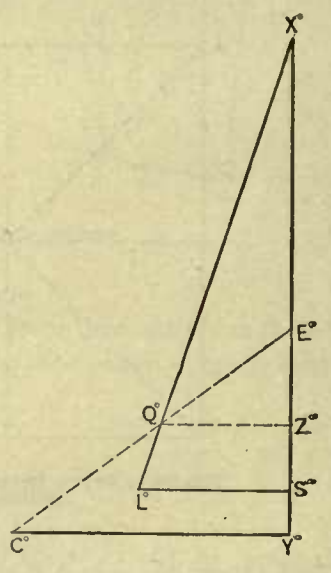


Fig. 447.—Section of Spire on Line of Hip.

Pattern for an Octagon Spire Mitering Upon a Roof at the Junction of the Ridge and Hips.

Also let D E F G be the side elevation of roof, and A″ *a′ c′* C″ the corresponding plan. In the front ele- | In the side elevation the spire is represented by P X U T R Q, and in plan by P′ Q′ R′ T′ U′ V′. Only

the points in plans are designated by letters which represent similar points in the elevation. In order to draw the plans and elevations, including the miter lines, it may be found convenient to first construct the entire octagons, as indicated in the plans, and from these to project the elevations above, as shown. From the point u in front elevation, which represents the intersection of one of the rear angles of the spire with the roof, carry a line parallel with B F, cutting X p. From the point U draw the miter line U T, and from the points V U drop perpendiculars to plan, cutting X′ V′ and X′ U′, from which points can be drawn the miter lines V′ U′ T′ of the plan.

To obtain the miter line P′ Q′ R′ of plan, from which is obtained the miter line Q R of side elevation, a diagram has been constructed in Fig. 447 which shows a section of spire and roof on the line C″ X′ of plan. To construct the diagram proceed as follows: Draw any line, as X° Y°. From X° set off the distance X E of side elevation or W B of front elevation. The point E° represents the junction of hip and ridge. From X° set off the distance X S, and erect the perpendicular S° L°, making it in length equal to S P, and connect L° X°. Then X° S° L° is a duplicate of X S P. From X° set off the distance X Y and erect the perpendicular Y° C°, in length equal to X′ C″ of plan, and connect C° E°. Then L° X° represents one side of spire, and C° E° the hip of the roof, and the point Q° the point of junction between the two.

As the spire is a perfect octagon, the profile of the side just constructed is in nowise different from either of those shown in the elevations. It simply has in addition the profile of one of the hips by means of which the correct hight of its intersection with the same (the point Q°) is determined. Draw Q° Z° parallel with C° Y°, and from the point X′ of plan set off the distance Z° Q° of diagram, as shown by X′ Q′. Connect R′ Q′ and Q′ P′. From the point Q′ in plan carry a line parallel with the center line X X′, cutting the hip line D E at Q. Draw Q R, which shows the miter line in side elevation. From the point Q can be drawn the line Q J, cutting the hip lines A B and B C in front elevation at the points J and N, and the miter lines J K and M N drawn. The points K M in front elevation correspond with the points K′ M′ of plan.

For the pattern proceed as follows: Draw $l\ x$ of Fig. 448, equal to P X of side elevation, and from l erect the perpendiculars $l\ p$ and $l\ p'$, equal in length to L′ P′ of plan or L M of front elevation. From p and p' draw lines to x, as shown. From x as center, with $x\ p$ as radius, describe an arc, as shown by $p'\ e$, indefinite in length. Set the dividers to the distance $p'\ p$ and step off spaces from p, as $p\ r$, $r\ t$, etc., until as many sides are set off as are desired to be shown in one part of the pattern. For convenience in describing the pattern draw the lines $x\ r$, $x\ t$, $x\ c$. Connect c and e and make $c\ d$ equal to $p\ l$ and draw $x\ d$. Bisect $p\ r$ and draw $x\ a$, and from x, on $x\ a$, set off the distance X° Q° of Fig. 447, locating the point q. Draw $p\ q$ and $q\ r$. From x, on $x\ d$, set off the distances X V and X U of side elevation, locating the points v and i. Through i draw a perpendicular cutting $x\ c$ and $x\ e$ in the points u and u', then draw $u'\ v\ v\ u$ and $u\ t$. Then $x\ p'\ p\ q\ r\ t\ u\ v\ u'$ is the pattern for part of spire shown on plan by X′ I P′ Q′ R′ T′ U′ V′ I′.

Fig. 448 shows a little more than half the full pattern, which will be readily understood by a comparison of reference letters.

PROBLEM 122.

The Envelope of a Right Cone.

In Fig. 449 let A B C be the elevation of the cone and D E F the plan of the same. To obtain the envelope set the compasses to the space B A, or the slant hight of the cone, as a radius, and from any convenient point as center, as B¹ of Fig. 450, strike an arc indefinitely. Connect one end of the arc with the center, as shown by A¹ B¹.

With the dividers, using as small a space as is

convenient, step off the circumference of the plan D E F, counting the spaces until the whole, or exactly

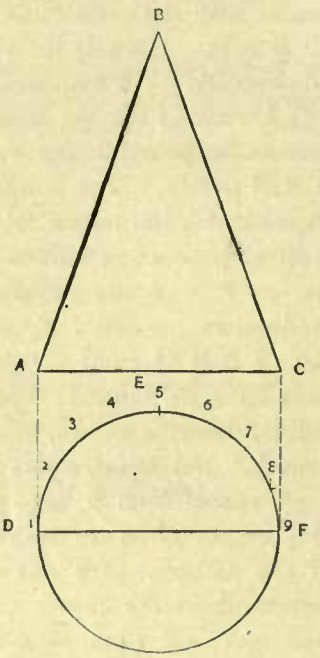


Fig. 449.—Plan and Elevation.

B' A' C' will be the pattern for the envelope of the cone A B C.

It is not necessary that all of the spaces used in measuring the circumference of the plan should be equal. It frequently happens that when the space assumed between the points of the dividers has been stepped off upon the circumference of the base, a space will remain at the finish smaller than that originally

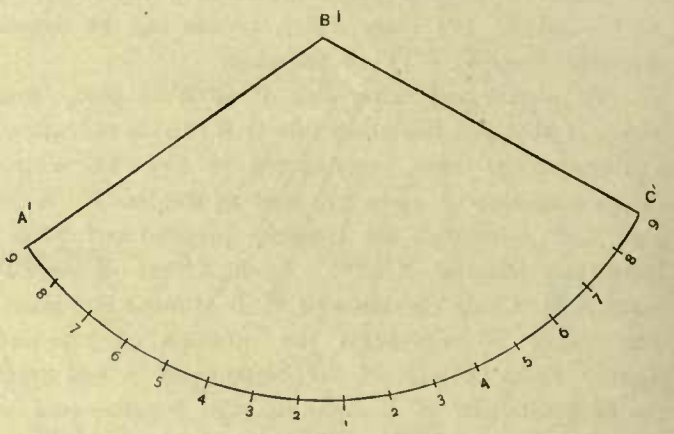


Fig. 450.—Pattern.

The Envelope of a Right Cone.

one half, is completed, as shown in the upper half of the plan. Then set off on the arc A' C' of the pattern, commencing at A', the same number of spaces as is contained in the entire circumference of the plan. Connect the last point C' with the center B'. Then assumed. In that case the required number of full spaces can be stepped off upon the arc of the pattern, after which the remaining small space may be added, thus completing the correct measurement of the pattern.

PROBLEM 123.

The Envelope of a Frustum of a Right Cone.

The principle involved in cutting the pattern for the frustum of a cone is precisely the same as that for cutting the envelope of the cone itself. The frustum of a right cone is a shape which enters so extensively into articles of tinware that an ordinary flaring pan, an elevation and plan of which are shown in Fig. 451, has been engraved for the purpose of illustration. An inspection of the engraving will show that C D, the top of the pan, is the base of an inverted cone, its apex B being at the intersection of the lines D O and C A forming the sides of the pan; and that A D is the top of the frustum or the base of another cone, A O B, which remains after cutting the frustum from the original cone. For the pattern then proceed as follows:

Through the elevation draw a center line, K B, indefinitely. Extend one of the sides of the pan, as, for example, D O, until it meets the center line in the point B. Still greater accuracy will be insured by extending the opposite side of the pan also, as shown—the three lines meeting in the point B—which determines the apex of the cone to a certainty. Then B O and B D, respectively, are the radii of the arcs which contain the pattern. From B or any other convenient point as center, with B O as radius, strike the arc P Q indefinitely, and likewise from the same center, with B D as radius, strike the arc E F indefinitely. From the center B draw a line across these arcs near one end, as P E, which will be an end of the pattern. By inspection and measurement of the plan determine in how many pieces the pan is to be constructed and divide the circumference of the pan into a corresponding number of equal parts, in this case three, as shown by K, M and L. With the dividers or spacers step off the length of one of these parts, as shown from M to L, and set off a corresponding number of spaces on the arc E F, as shown. Through the last division draw a line across the arcs toward the center B, as shown by F Q. Then P Q F E will be the pattern of one of the sections of the pan, as shown in the plan.

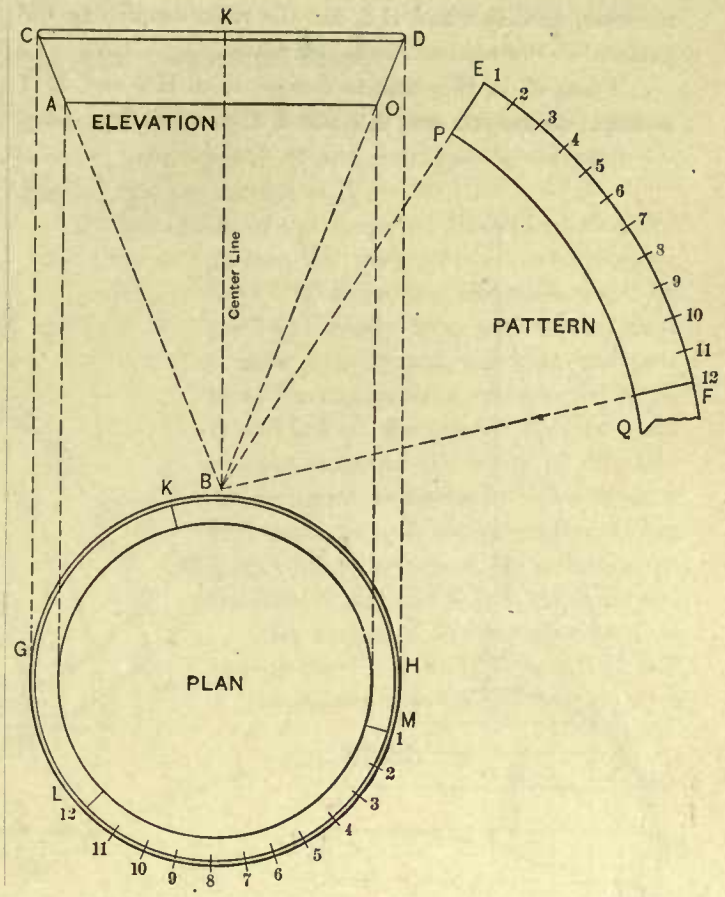


Fig. 451.—The Envelope of the Frustum of a Right Cone.

PROBLEM 124.

To Construct a Ball in any Number of Pieces, of the Shape of Zones.

In Fig. 452, let A I G H be the elevation of a ball which it is required to construct in thirteen pieces. Divide the profile into the required sections, as shown by 0, 1, 2, 3, 4, etc., and through the points thus obtained draw parallel horizontal lines, as shown. The divisions in the profile are to be obtained by the following general rule, applicable in all such cases: Divide the whole circumference of the ball into a number of parts equal to two times one less than the number of pieces of which it is to be composed.

In convenient proximity to the elevation, the center being located in the same vertical line A N, draw a plan of the ball, as shown by K M L N. Draw the diameter K L parallel to the lines of division in the elevation. With the -square placed at right angles to this diameter, and brought successively against the points in the elevation, drop corresponding points upon it, as shown by 1, 2, 3, 4, etc. Through each of these points describe circles from the center by which the plan is drawn. Each of these circles becomes the plan of one edge of the belt in the elevation to which it corresponds in number, and is to be used in establishing the length of the arc forming the pattern of the zone of which it is the base. Extend the center line N A in the direction of O indefinitely. Draw chords to the several arcs into which the profile has been divided, which produce until they cut G A O, as shown by 1 2 E, 2 3 D, 3 4 C, 4 5 B and 5 6 A. Then E 2 and E 1 are the radii of parallel arcs which will describe the pattern of the first division above the cen-

ter zone, and D 3 and D 2 are the radii describing the pattern of the second zone, and so on.

From E' in Fig. 453 as center, with E 2 and E 1 as radii, strike the arcs 2 2 and 1 1 indefinitely. Step off the length on the corresponding plan line, and make 1 1 equal to the whole of it, or a part, as may be desired—in this case a half. In like manner describe patterns for the other pieces, as shown, struck from the centers D', Fig. 454; C', Fig. 455; B', Fig. 456, and A', Fig. 457. The pattern for the smallest section, as indicated by F in the plan, may be struck by a radius equal to F 6 in the plan. The center belt or zone, shown in the profile by 1 0, is a flat band, and is therefore bounded by straight parallel lines, the width being 1 0 in the elevation, and the length measured upon line 1 of the plan, all as shown in Fig. 458.

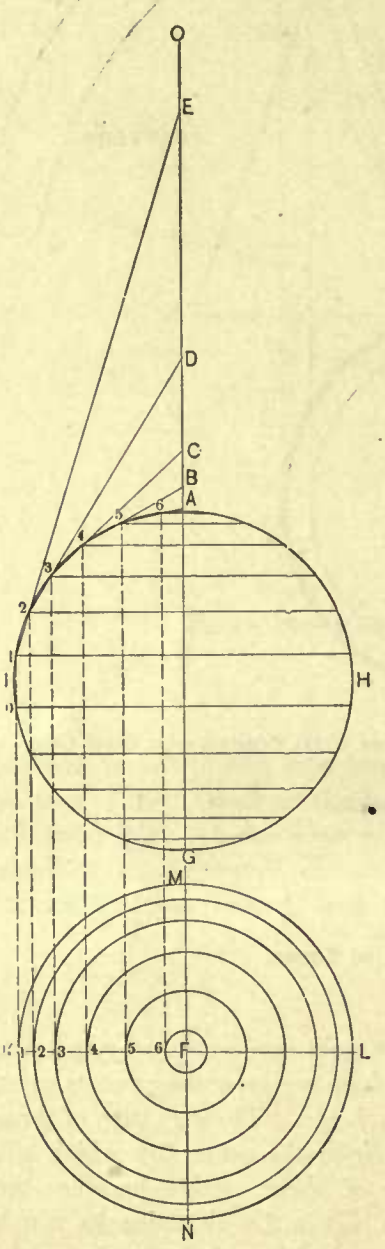


Fig. 452.—Plan and Elevation.

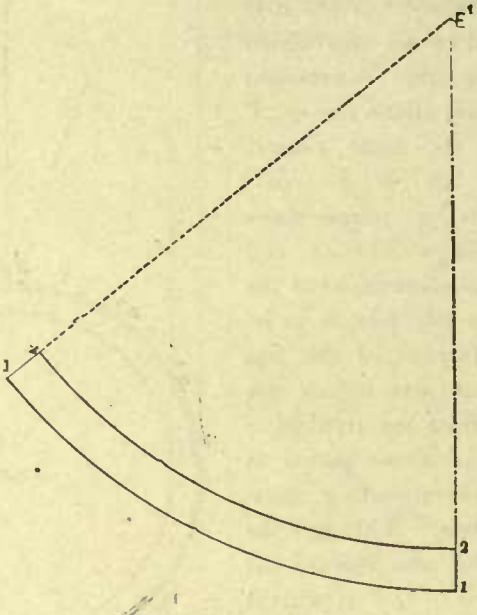


Fig. 453.—Pattern of Zone 1 2.

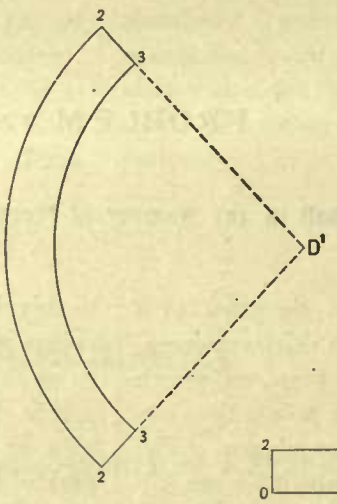


Fig. 454.—Pattern of Zone 2 3.

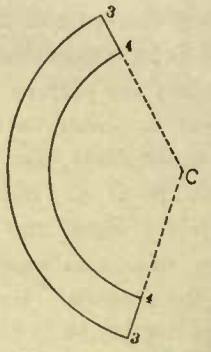


Fig. 455.—Pattern of Zone 3 4.

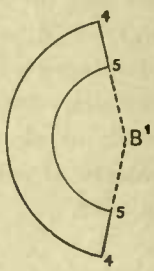


Fig. 456.—Pattern of Zone 4 5.

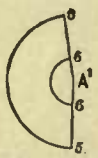


Fig. 457.—Pattern of Zone 5 6.

Fig. 458.—Pattern of Middle Zone.

To Construct a Ball in any Number of Zones.

PROBLEM 125.

The Patterns for a Semicircular Pipe with Longitudinal Seams.

By the nature of the problem the pipe resolves itself, with respect to its section or profile, into some regular polygon. In the illustration presented in Fig. 459 an octagonal form is employed, but any other regular shape may be used, and the patterns for it will be cut by the same rule as here explained. Let N L V be any semicircle around which an octagonal pipe is to be carried. Draw N V, passing through the center W. Through W draw the perpendicular L K indefinitely. Let N R be the required diameter of the octagon. Immediately below and in line with N R construct the profile A B C D F H G E and project the points B and C back upon N R and complete the elevation by drawing the semicircles O U and P T.

By inspection of the diagram it is evident that the pattern for the sections corresponding to O U T P in the elevation may be pricked directly from the drawing as it is now constructed, and that the patterns for the sections represented by E A and D F of the profile will be plain straight strips of the width of one side of the figure, as shown by either E A or D F, and in length corresponding to the length of the sweep of the elevation on the lines N L V and R X S, respectively.

By virtue of the bevel or flare of the pieces N L V U T and R X S T P, as shown by A B and C D of the profile, each becomes one-half of the frustum of a right cone, with its apex above or below the point W. Therefore prolong C D of the profile until it cuts the center line L K of the elevation in the point M. Then M D and M C are the radii of the pieces corresponding to P T S R of the elevation. Also prolong the side A B, or, for greater convenience, its equivalent, E G, until it

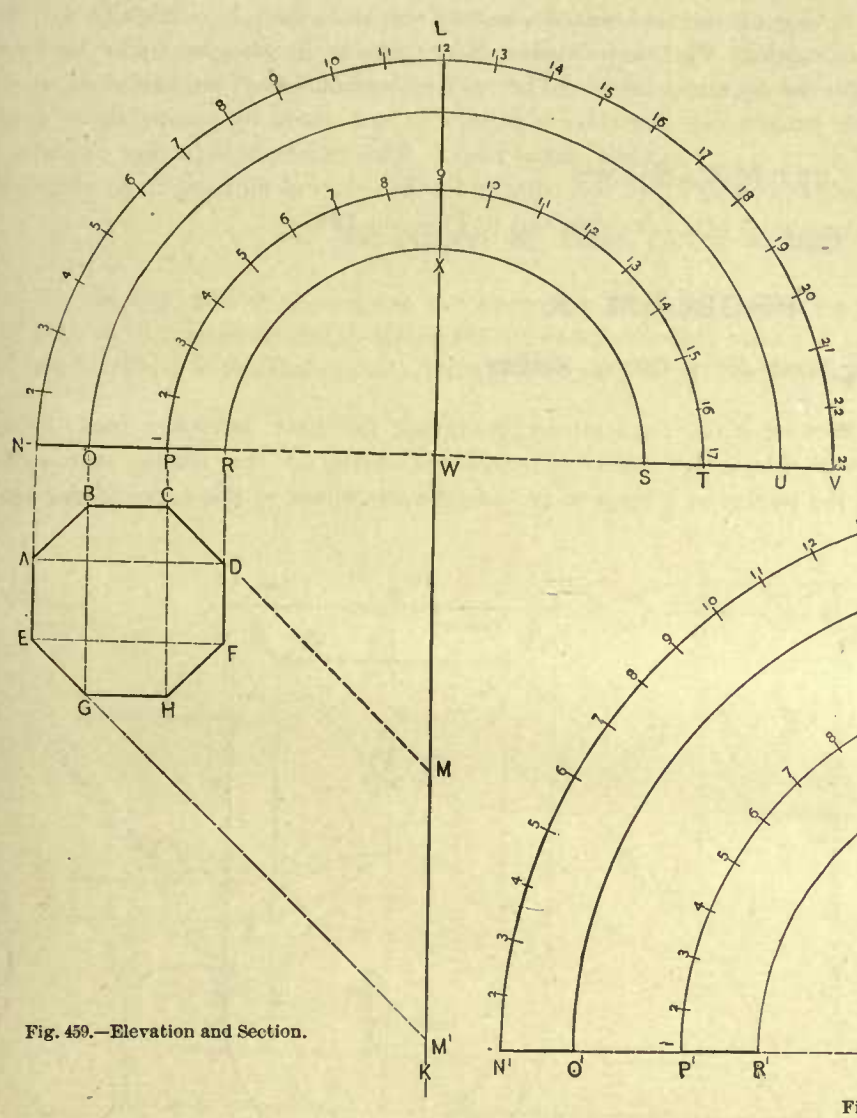


Fig. 459.—Elevation and Section.

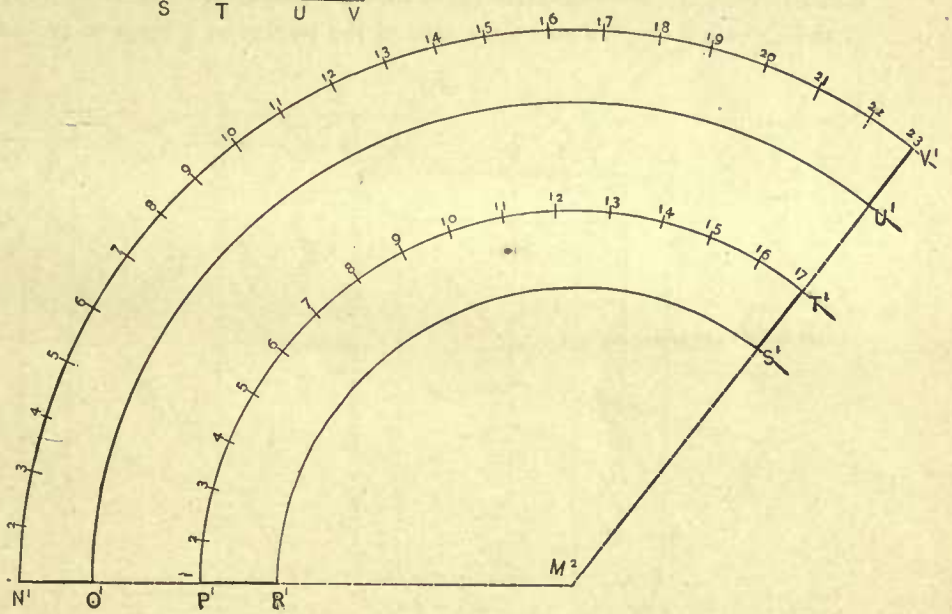


Fig. 460.—Pattern.

A Semicircular Pipe with Longitudinal Seams.

cuts the center line in the point M'. Then M' G and M' E are the radii of the pieces corresponding to N L V U O of the elevation. From M² in Fig. 460 as center, using each of the several radii in turn, strike arcs indefinitely, as shown by N' V', O' U', P' T' and R' S'. Step off the length N L V in the elevation, Fig. 457, and make N' V' of Fig. 458 equal to it. Draw N' O' and V' U' radial to M². Then N' V' U' O' will constitute the pattern for the pieces N L V U O of the elevation. In like manner establish the length of P' T', and draw P' R' and T' S', also radial to the center, as shown. Then P' T' S' R' will be the pattern for the pieces P T S X R of the elevation.

This rule may be employed for carrying any polygonal shape around any curve which is the segment of a circle. The essential points to be observed are the placing of the profile in correct relationship to the elevation and to the central line L K, after which prolong the oblique sides until they cut the central line, thus establishing the radii by which their patterns may be struck. In the case of elliptical curves, by resolving them into segments of circles and applying this rule to each segment, as though it were to be constructed alone and distinct from the others, no difficulty will be met in describing patterns by the principles here set forth. The several sections may be united so as to produce a pattern in one piece by joining them upon their radial lines. This principle is further explained in the pattern for the curved molding in an elliptical window cap in Problem 128.

PROBLEM 126.

The Blank for a Curved Molding.

As curved moldings necessitate a stretching of the metal in order to accommodate them to both the curve of the elevation or plan and the curve of the profile at the same time, the patterns for their blanks can only be considered as flaring strips of metal in which the curve of the elevation or plan only is considered. The curve of the profile requires to be forced into them by machinery designed for that purpose, care being taken to make the width of the flaring strip sufficient to include the stretchout of the curve of the profile. Blanks for curved moldings thus become frustums of cones and are cut according to the principles of regular flaring articles, as explained in the preceding problems. The method of determining the exact flare

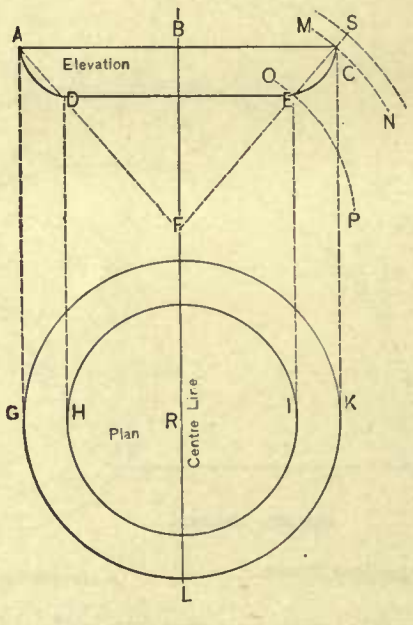


Fig. 461.—Obtaining the Blank for a Curved Cove or Ovolo Molding.

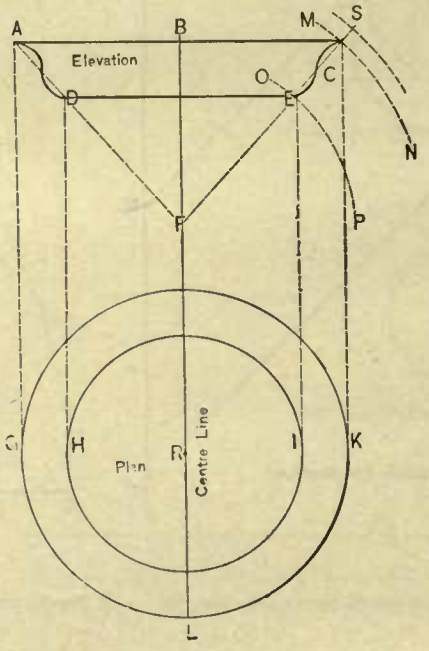


Fig. 462.—Obtaining the Blank for a Curved Ogee Molding.

necessary to produce a certain mold with the greatest facility is a matter to be determined by the nature of the profile and the kind of machinery to be used in forming the same. Usually a line is drawn through the extremities of the profile, as shown at A D in either of the two illustrations here given, Figs. 461 and 462, and is continued until it meets the center line, for length of radius, as shown at F.

Therefore, to describe the pattern of the blank from which to make a curved molding corresponding to the elevation A C E D, proceed in the same manner as though the side E C were to be straight. Through the center of the article draw the line B F indefinitely, and draw a line through the points C and E of one of the sides, which produce until it meets B F in the point F. Then F E will be the radius of the inside of the pattern. The radius of the outside is to be obtained by increasing F C an amount equal to the excess of the curved line E C over the straight line E C, as shown by the distance C S. Then F S is the radius of the outside of the pattern. The length of the pattern can be obtained as in previous problems.

PROBLEM 127.

The Patterns for Simple Curved Moldings in a Window Cap.

In Fig. 463 is shown the elevation of a window cap, in the construction of which two curved moldings are required of the same profile, but curved in opposite directions. It is advisable to include as much in one piece as can be raised conveniently with the means at hand; therefore, the curved part of the profile with its fillets or straight parts adjacent and the two edges necessary for joining it to the face and roof pieces will be obtained in one piece. The method of developing the pattern for the blank is the same for both curves. The two pieces will raise to the form by the same dies or rolls, it being necessary only to reverse them in the machine. Before the blank for the middle piece can be developed it will be necessary to first construct a

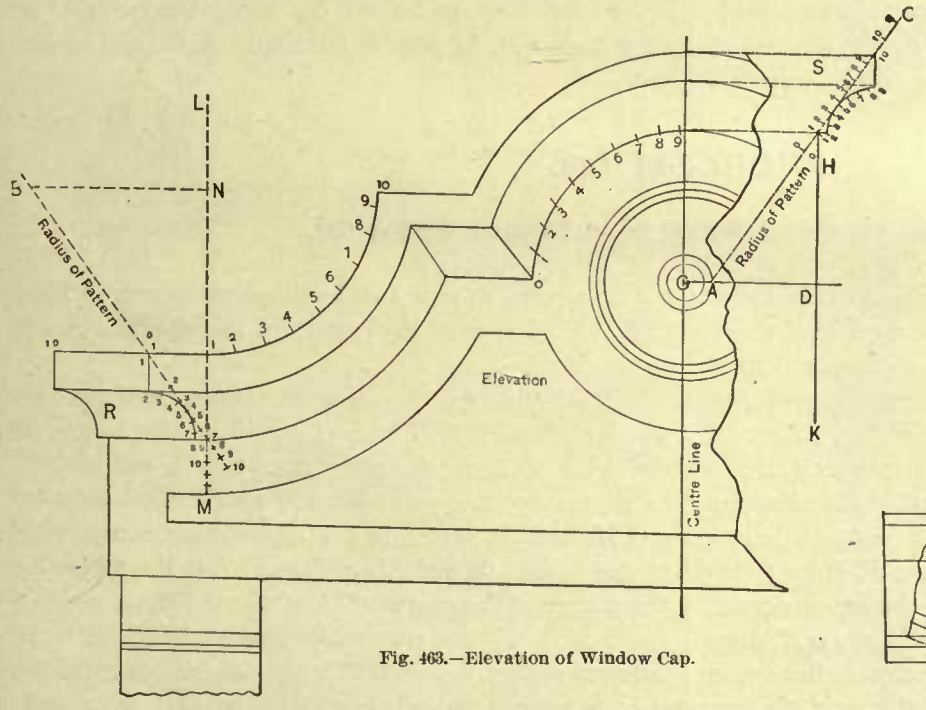


Fig. 463.—Elevation of Window Cap.

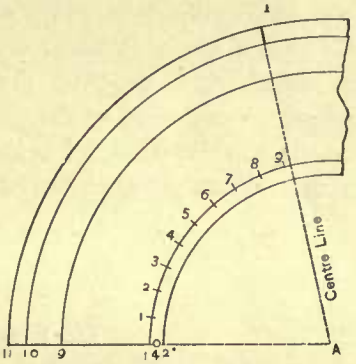


Fig. 464.—Blank for Center Piece.

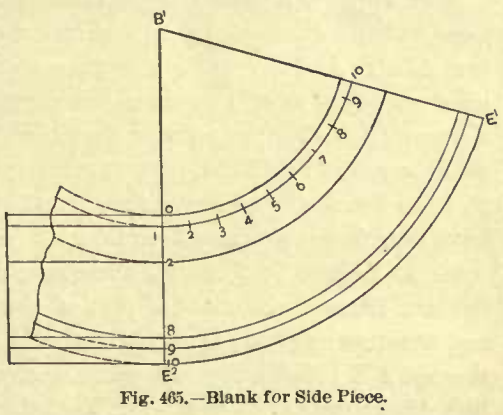


Fig. 465.—Blank for Side Piece.

The Patterns for Simple Curved Moldings in a Window Cap.

section upon the center line, as shown at S K; from all points in the mold and the center of the curve upon the center line project horizontal lines to the right. Draw any vertical line, as H K, to represent the face of the cap in the section and at S draw the profile of the mold, as shown. The principle to be employed in striking the pattern is simply that which would be used in obtaining the envelope of the frustum of a cone of which A D is the axis.

The general average of the profile is to be taken in establishing the taper of the cone, or, in other words, a line is passed through its extreme points. Draw a line through the profile in this manner and prolong it until it intersects A D in the point A, all as shown by C A. Then A is the apex of the cone, of which A C is the side and H D the top of the frustum. Divide the profile S, as in ordinary practice for stretchouts, into any number of spaces, all as shown by the small figures. Transfer the stretchout of the profile S on to the line A C, commencing at the point 1, as shown, letting the extra width extend in the direction of C. From any convenient center, as A in Fig. 464, with radius A C, describe the pattern, making the length of the arc equal to the length of the corresponding arc in the elevation, all as shown by the spaces and numbers. From the same center draw arcs corresponding to points 9, 10 and 11 of the stretchout, thus completing this pattern.

For the pattern of the curved molding forming the end portion of the cap proceed in the same general manner. Upon any line drawn through the center N of the curve, as L M, construct a section of the mold, as shown at R. From N draw the perpendicular N B indefinitely. Through the average of the profile R, as before explained, draw the line to B, cutting N B in the point B, as shown. Lay off the stretchout of the profile upon this line, commencing at the point 1, in the same manner as explained in the previous operation. From any convenient point, as B^1 in Fig. 465, as center, with radius B 1, describe the inner curve of the pattern, as shown, which in length make equal to the elevation, measuring upon the arc 1, all as shown by the small figures, after which add the outer curves, as shown by E^1 E^2.

The straight portion forming the end of this molding, as shown in the elevation, is added by drawing, at right angles to the line E^2 B^1, a continuation of the lines of the molding of the required length, as shown in the pattern. Upon this end of the pattern a square miter is to be cut by the ordinary rule for such purposes, to join to the return at the end of the cap.

PROBLEM 128.

The Pattern for the Curved Molding in an Elliptical Window Cap.

In Fig. 466 is shown the elevation and vertical section of a window cap elliptical in shape, the face of which is molded. In drawing the elevation such centers have been employed as will produce the nearest approach to a true ellipse after the manner described in Problem 76 of Geometrical Problems, page 65. The centers B, D and F, from which the respective segments of the elevation have been described, may then be used in obtaining patterns as follows: Through the center F, from which the arc forming the middle part of the cap is drawn, and at right angles to the center line of the cap G H, draw the line I K indefinitely. Project a section on the center line of the cap, as shown by P K at the right, the line P K being used as a common basis of measurement upon which to set off the semi-diameters of the various cones of which the blanks for the moldings form a part. Through the average of the profile, as indicated, draw S R, producing the line until it meets I K. Divide the profile of the molding in the usual manner and lay off the stretchout, as indicated by the small figures. Then R S is the radius of the pattern of the middle segment of the cap.

With the dividers, measuring down from the profile, lay off on P K distances equal to the length of the radius A B, as shown by the point O, and of C D, as shown by the point M. Through these points O and M, at right angles to P K, draw lines cutting S R in the points T and U. Then U S is the radius for the pattern of the segment C E of the elevation, and T S the radius of the pattern for the segment A C. In order to obtain the correct length of the pattern, not only as regards the whole piece, but also as regards the length of each arc constituting the curve, step off the length of the curved molding with the dividers upon any line of the elevation most convenient, as shown, numbering the spaces as indicated, and setting off a like number of spaces upon a corresponding line of the pattern. As a matter both of convenience and

accuracy, the spaces used in measuring the arcs are greater in the one of longest radius and are diminished in those of shorter radii, as will be noticed by examination of the diagram.

To lay off the pattern after the radii are obtained as above described, proceed as follows: Draw any straight line, as G' H' in Fig. 467, from any point in which, as F', with radius equal to R S, as shown by F' E', describe an arc, as shown by E' G'; and likewise, from the same center, describe other arcs corresponding to other points in the stretchout of the profile. Make the length of the arc E' G' equal to the length of the corresponding arc in the elevation, as described above. From E' to the center F', by which this arc was struck, draw E' F'. Set the dividers to the distance U S as radius, with which, measuring from E' along the line E' F', establish D' as center, from which describe arcs corresponding to the points in the profile, as shown from E' to C'. Make E' C' equal to the length of the corresponding arc in the elevation, all as shown by the small figures. From C' draw the line C' D' to the center by which this arc was struck. Set the dividers to the distance T S in the section, and, measuring from C' along the line C' D', establish the point B', from which as a center strike arcs cor-

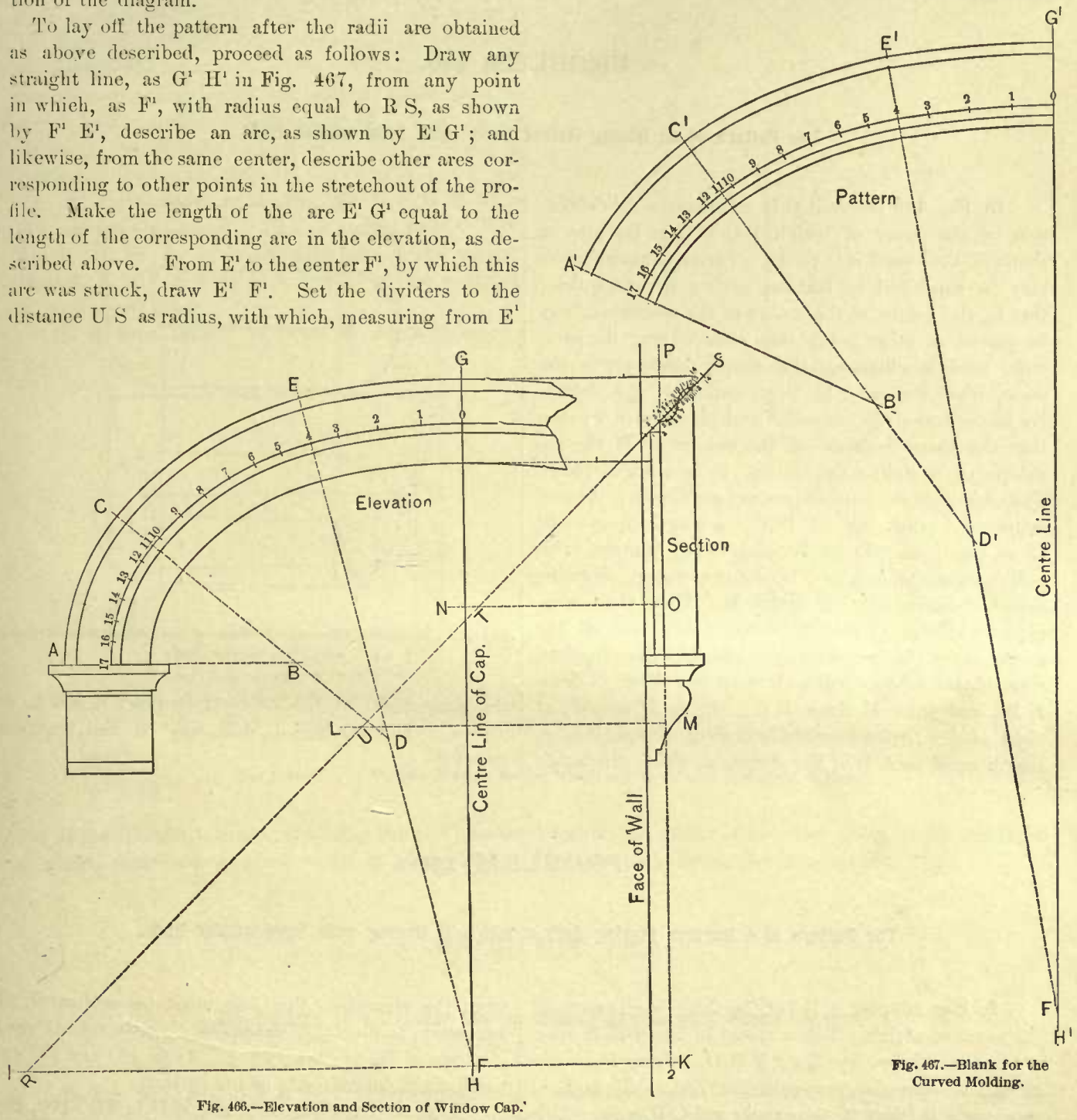


Fig. 466.—Elevation and Section of Window Cap.

Fig. 467.—Blank for the Curved Molding.

The Pattern for the Curved Molding in an Elliptical Window Cap.

responding to those already described in the other section of the pattern. Make the length equal to the length of the corresponding segments in the elevation, and draw the line A' B'. Then A' C' E' G' is the half pattern corresponding to A C E G of the elevation.

PROBLEM 129.

The Pattern of an Oblong Raised Cover with Semicircular Ends.

In Fig. 468 let A B C D represent a side elevation of the cover of which E G F H is the plan or shape of the vessel it is to fit. Various constructions may be employed in making such a cover as this; that is, the joints, at the option of the mechanic, may be placed at other points than shown here; the principle used in obtaining the shape, however, is the same, whatever may be the location of the joints. By inspection of the elevation and plan it will be seen that the shape consists of the two halves of the envelope of a right cone, joined by a straight piece. Therefore, for the pattern proceed as follows: At any convenient point lay off B^2 C^2, in length equal to B^1 C^1 of the plan. From B^2 and C^2 as centers, with radius equal to A B or C D of the elevation, describe arcs, as shown by O N and P M. Upon these arcs, measured from O and P, respectively, set off the stretchout of the semicircular ends, as shown in plan, thus obtaining the points M and N. From N draw N B^2, and from M draw M C^2. From B^2 and C^2, at right angles to the line B^2 C^2, draw B^2 K and C^2 L, in length equal to A B of the elevation, which represents the slant hight of the article. Connect K and L, as shown. Then O N K L M P will be the required pattern.

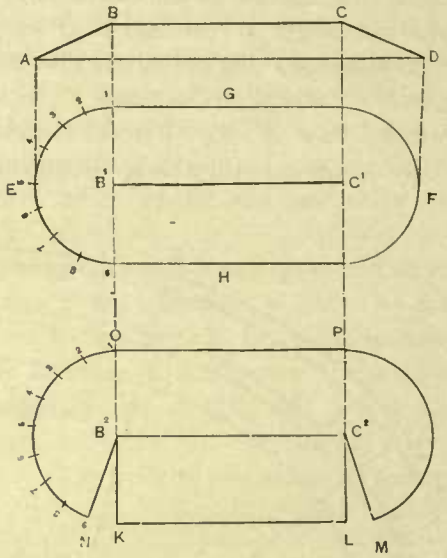


Fig. 468.—Elevation, Plan and Pattern of an Oblong Raised Cover with Semicircular Ends.

PROBLEM 130.

The Pattern of a Regular Flaring Article which Is Oblong with Semicircular Ends.

In Fig. 469, let A B D C be the side elevation of the required article. Below it and in line with it draw a plan, as shown by E *c d* F H G. From D in the elevation erect the perpendicular D L. Then L C represents the flare of the article and C D is the width of the pattern throughout. Across the plan, at the point where the curved end joins the straight sides, draw the line *d* H at right angles to the sides of the article. As the plan may be drawn at any distance from the elevation, this line must be prolonged, if necessary, to meet C D extended. Produce C D until it meets *d* H, as shown by *g*. Then *g* D and *g* C are radii of the curved parts of the pattern.

Lay off on a straight line M O in Fig. 470, the length of the straight part of the article, as shown in the plan by *c d*. At right angles to M O draw M S and O R indefinitely. Upon these lines set off from M and O the distance *g* C, locating the points S and R,

the centers for the curved portions of the pattern. From S with the radius g C strike the arc M U indefinitely. In like manner, with same radius, from R as center describe the arc O V. From the same centers, with radius equal to g D, describe the arcs N T and P W. Step off the length of the curved part of the article upon either the inner or outer line of the plan, and make the corresponding arc of the pattern equal to it, as shown by the spaces in N T and P W. Through the points T and W draw lines from the centers S and R, producing them until they cut the outer arcs at U and V. At right angles to the line S T U or R W V, as the case may be, set off V X Y W, equal to M O P N, which will be the other straight side of the pattern. Then U M O V X Y W P N T will be the complete pattern in one piece.

If it were desired to locate the seam midway in one of the straight sections, in adding the last member as above described, one-half would be placed at each end, instead of all at one end, as shown. In like manner such changes may be made as are necessary for locating the seam at any other point, or for cutting the pattern in as many pieces as desired.

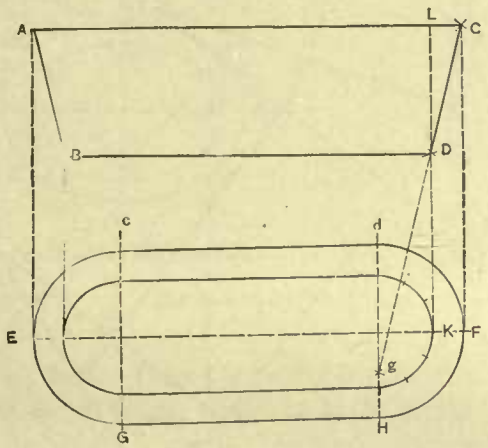


Fig. 469.—Plan and Elevation.

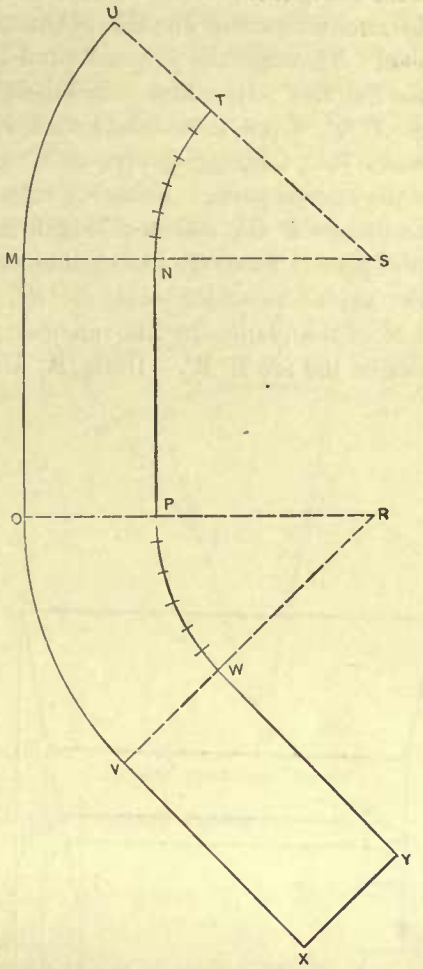


Fig. 470.—Pattern.

The Pattern of a Regular Flaring Article Which is Oblong with Semicircular Ends.

PROBLEM 131.

The Pattern of a Regular Flaring Oblong Article with Round Corners.

In Fig. 471, A C D B is the side elevation of the article and E F G M N O P R the plan. The corners are arcs of circles, being struck by centers H, L, T and S, as shown. Draw the plan in line with the elevation, so that the same parts in the different views shall correspond. Through the centers H and L of the plan by which the corners F G and M N are struck, draw F N indefinitely. Prolong the side line of the elevation C D until it cuts F N in the point K, as shown. Then K D is the radius of the inside line of

the pattern of the curved part, and K C is the radius of the outside line.

Draw the straight line E' F' of Fig. 472, in length equal to the straight part of one side of the article, or E F of the plan. Through the points E' and F', at right angles to the line E' F', draw lines indefinitely, as shown by E' U and F' K'. Upon these lines set off, from F' and E', the distance K C, locating the points K' and U, the centers for the curved parts. From K', with the radius K C, strike the arc F' G', which in length make equal to F G of the plan. From G' draw a line to the center K', at right angles to which erect G' M', in length equal to G M of the plan. In like manner, with like radius, describe the arc E' R'. Draw R' U, at right angles to which erect R' P', equal to R P of the plan. At right angles to R' P' draw P' V indefinitely. In the manner above described establish the center V, and from it describe the third arc P' O'. Draw O' V. At right angles to it lay off O' N', equal to O N of the elevation. Draw N' W, and draw the arc N' M² in the same manner as already described. In the same manner lay off the inner line of the pattern, as shown by *m g f e r p o n m'*. Join the ends M' *m* and M² *m'*, thus completing the pattern sought.

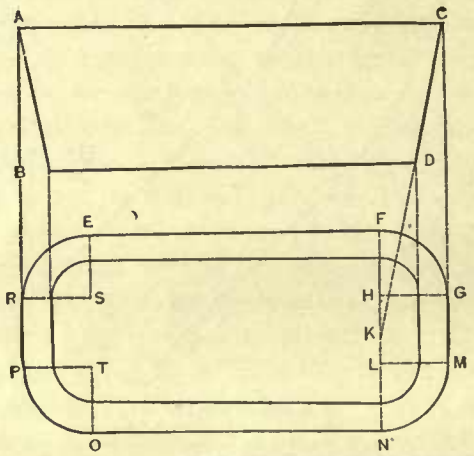


Fig. 471.—Plan and Elevation.

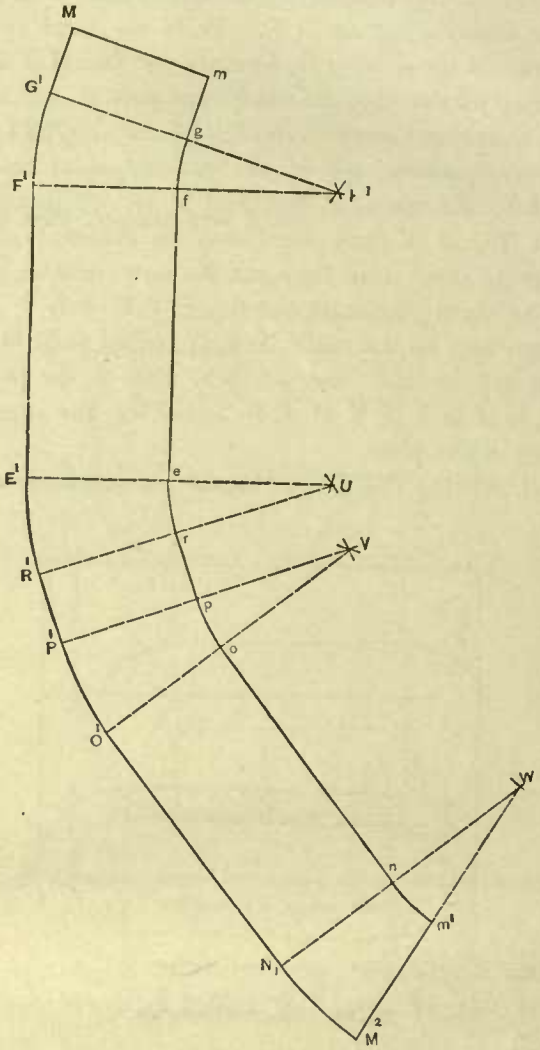


Fig. 472.—Pattern.

The Pattern of a Regular Flaring Oblong Article With Round Corners.

PROBLEM 132.

The Envelope of the Frustum of a Cone, the Base of Which Is an Elliptical Figure.

This shape is very frequently used in pans and plates, and therefore in Fig. 473 is shown an elevation and plan of what is familiarly termed an oval flaring pan. Let that part of the plan lying between H and L be an arc whose center is at U, and let those portions between V and H and L and W be arcs whose

centers are, respectively, R and S. A C D B represents an elevation of the vessel, and is so connected with the plan as to show the relationship of corresponding points.

The first step is to construct a diagram, shown in Fig. 474, by means of which the lengths of the radii to be used in describing the pattern are to be obtained. Draw the horizontal line H U indefinitely, and at right angles to it draw H A, indefinitely also. Make H U equal to H U of the plan, Fig. 471. Make H C equal to the vertical hight of the vessel, as shown in the elevation by D X. Draw the line C G parallel to H U, making C G in length equal to U N of the plan. Through the points U and G thus established draw the line U G, which continue until it meets H A in the point A. Then A U will be the radius by which to describe that portion of the pattern which is included between the points H and L of the plan. With A U as radius, and from any convenient point as center—as A, Fig. 475—draw the arc H L, which in length make equal to H L of the plan, Fig. 473, as shown by the points 1, 2, 3, etc. From the same center, and with the radius A G of Fig. 474, describe the parallel arc N O. From the points H and L of the arc first drawn draw lines to A, thus intercepting the arc N O and determining its length.

In the diagram, Fig. 474, set off from H, on the line H U, the distance R H, making it equal to R H of the plan, Fig. 473. Also, upon the line C G, from the point C, set off C I, equal to R N of the plan. Then, through the points R and I thus established, draw the line R B, which produce until it intersects A H. Then R B will be the radius for those portions of the pattern lying between V and H and L and W of the plan. From the point H, on the line H A, Fig. 475, set off the distance H B, equal to R B of Fig. 474. Then, with B as center, describe the arc E H, and from a corresponding center, C, at the opposite end on pattern, describe the arc L K. From the same centers, with B I as radius, describe the arcs N M and O P, all as shown. Make H E and L K in length equal to H E and L K of the plan. From E and K, respectively, draw lines to the centers B and C, intercepting the arcs N M and O P in the points M and P. Then E K P M will be one-half of the complete patterns of the vessel.

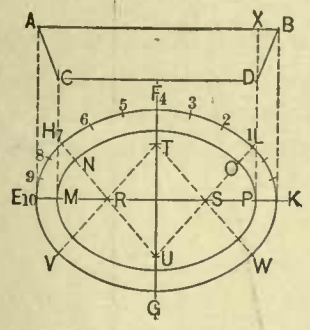


Fig. 473.—Plan and Elevation.

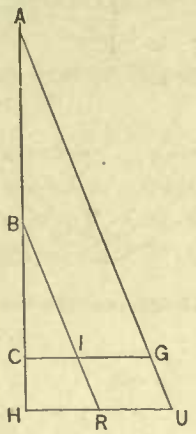


Fig. 474.—Diagram of Radii.

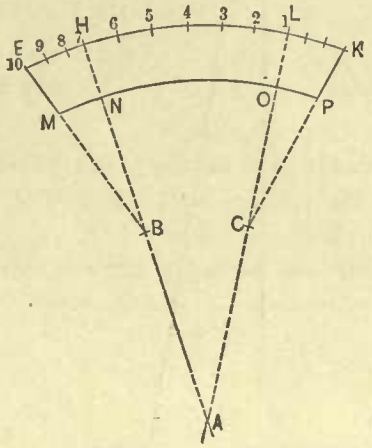


Fig. 475.—Pattern of One Half.

The Envelope of the Frustum of a Cone, the Base of Which is an Elliptical Figure.

PROBLEM 133.

The Pattern of a Heart-Shaped Flaring Tray.

Let E C G' F G C' of Fig. 476 be the plan of the article, and I N O K the elevation. By inspection of the plan it will be seen that each half of it consists of two arcs, one being struck from D or D' as center, and the other from C or C' as center, the junction between the two arcs being at G and G', respectively. From C

draw C F, and likewise draw C G. Upon the point D' erect the perpendicular D' C'.

To obtain the radii of the pattern construct a diagram, shown in Fig. 477, which is in reality a section upon the line C G of the plan. Draw X P in Fig. 477, in length equal to the straight hight of the article. Lay off the perpendiculars X U and P S indefinitely. Upon P S, from P, set off P R, equal to D' C' of the plan, and on X U, from X, set off X W, equal to D' *c* of the plan. In like manner make P S equal to C G of the plan, and X U equal to C *g* of the plan. Connect U S and W R. Produce P X indefinitely in the direc-

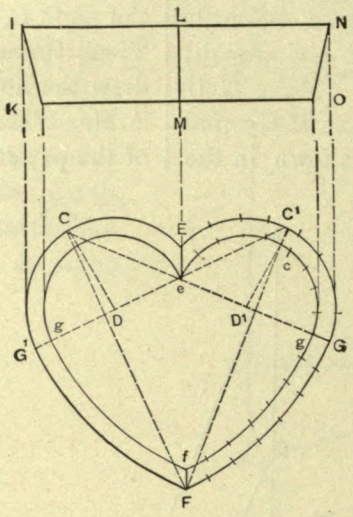


Fig. 476.—Plan and Elevation.

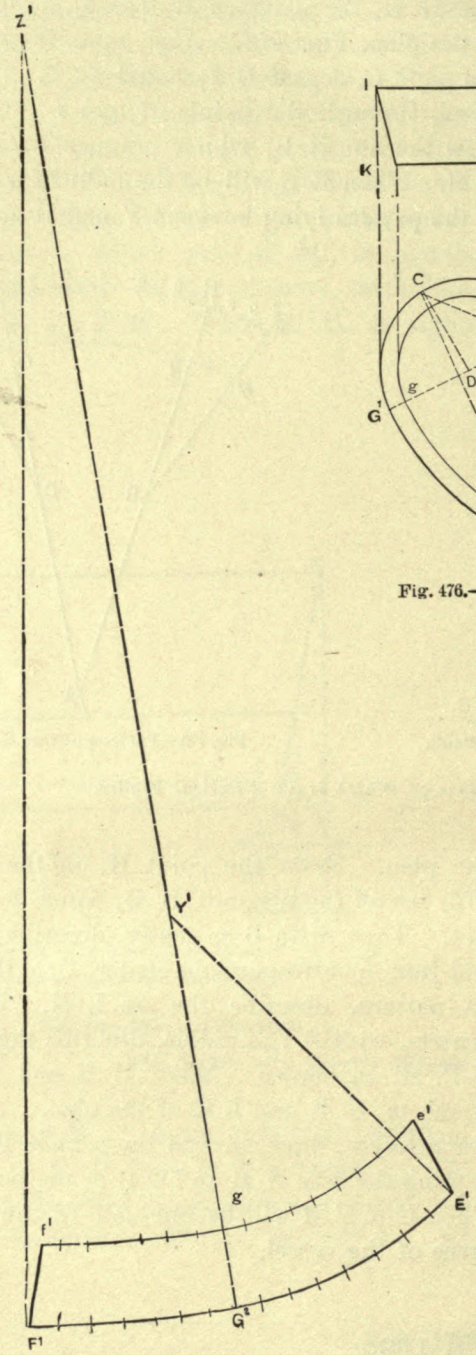


Fig. 478.—Pattern.

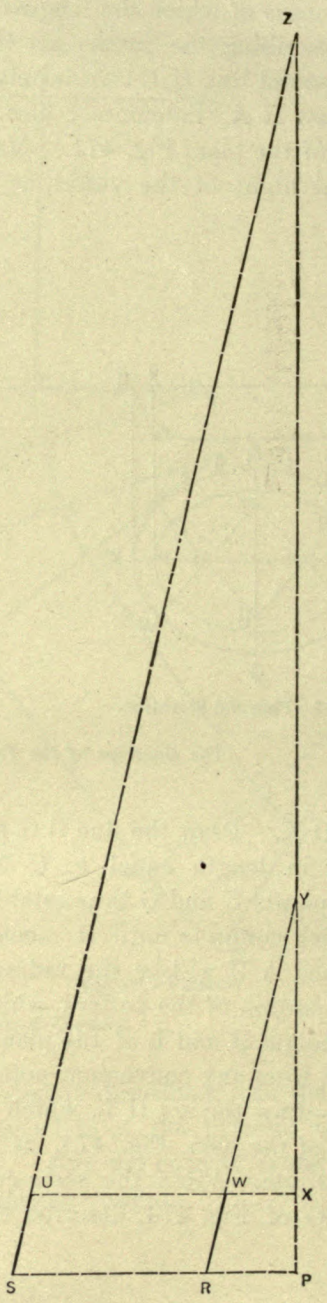


Fig. 477.—Diagram of Radii.

The Pattern of a Heart-Shaped Flaring Tray.

tion of Z. Also produce R W until it meets P X in the point Y, and in like manner produce S U until it meets P Z in the point Z. Then Z U and Z S are the radii for that portion of the article contained between G and F of the plan, and Y W and Y R are the radii of that portion shown from G to E of the plan.

To lay out the pattern after the radii are established, draw any straight line, as Z^1 G^2 in Fig. 478, in length equal to Z S of the diagram. From Z^1 as center, with Z S as radius, describe the arc G^2 F^1, in length equal to G F of the plan. In like manner, with radius Z U, from the same center, describe the arc g^1 f^1, in length equal to g f of the elevation. Draw f^1 F^1. Set off from G^2, upon the line G^2 Z^1, the distance R Y of Fig. 477, as shown at Y^1, and from Y^1 as center, with the radius R Y, describe the arc G^2 E^1, which in length make equal to G E of the plan. In like manner, from the same center, with radius Y W, describe the arc g^1 e^1, equal to the arc g e of the plan. Draw e^1 E^1, thus completing the required pattern.

PROBLEM 134.

The Pattern of an Oval or Egg-Shaped Flaring Pan.

Let A B C D in Fig. 479 represent the elevation of the article, of which A^1 K L B^1 M I is the plan. The plan is constructed by means of the centers O, P, F and F^1, as indicated. The patterns, therefore, are constructed a section of the article as it would appear if cut on the line A^1 P of the plan. Therefore set off, at right angles to it, A^2 P^2, equal to A^1 P. Make P^2 D^2 equal to the straight hight of the article, as

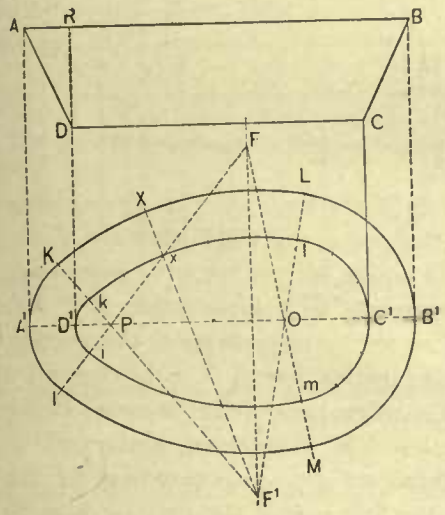


Fig. 479.—Plan and Elevation.

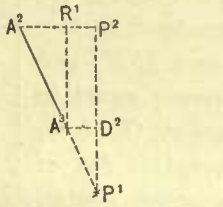


Fig. 480.—Diagram of Small Cone.

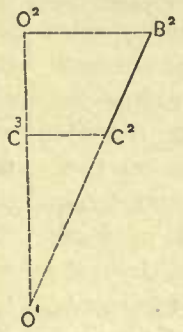


Fig. 481.—Diagram of Middle Cone.

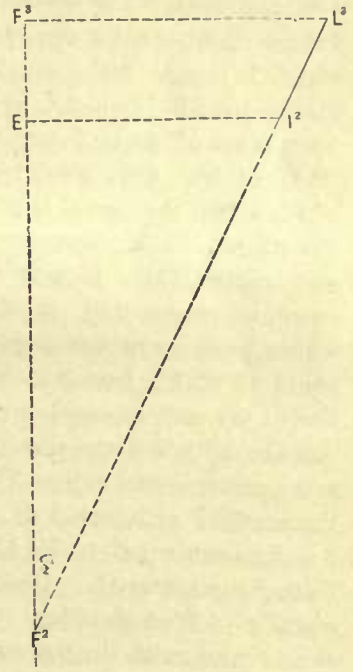


Fig. 482.—Diagram of Large Cone.

An Oval or Egg-Shaped Flaring Pan.

struck by radii obtained from sections of the several cones of which the article is composed. At any convenient place draw the line P^2 P^1, Fig. 480, indefinitely, corresponding to P of the plan, and upon it shown by R D of the elevation. Make D^2 A^3 of the diagram equal to D^1 P of the plan. Draw A^2 A^3, which will correspond to A D of the elevation, prolonging it until it meets P^2 P^1 in the point P^1. Then

P^1 A^2 is the radius of the outside line of the pattern of the portion between K and I of the plan, and P^1 A^3 is the radius of the line inside of the same part.

In like manner draw the line O^1 O^2, Fig. 481, corresponding to O of the plan, and construct a section taken on the line O B', as shown by O^2 B^2 C^2 C^3. Produce B^2 C^2 until it meets O^2 O^1 in the point O^1. Then O^1 C^2 and O^1 B^2 are the radii of the pattern of that portion of the article contained between L and M of the plan.

Draw the line F^3 F^2, Fig. 482, which shall correspond to F or F^1 of the plan. Make F^3 E equal to the straight hight of the article, and lay off F^3 L^3 at right angles to it, equal to F^1 L of the plan, and E l^2 equal to F^1 l of the plan. Draw L^3 l^2, which produce until it meets F^2 F^3 in the point F^4. Then F^2 l^2 and F^2 L^3, respectively, are the radii of the pattern of those parts shown by K L and I M of the plan.

To lay off the pattern after the several radii are obtained, as described above, draw any straight line, in length equal to F^2 L^3, as shown by F^4 K in Fig. 483, and from F^4 as center, with F^2 l^2 and F^2 L^3, Fig. 482, as radii, strike arcs, as shown by k^1 l^1 and K L', which in length make equal to the corresponding arcs of the plan K L and k l, as shown. Draw L^1 F^4, and upon it set off from l^1 toward F^4, a distance equal to O^1 C^2 of Fig. 481, establishing the point O^3, from which strike the arc l^1 m^1, in length equal to l m of the plan. In like manner, from the same center, with radius O^1 B^2, of Fig. 481, strike the arc L^1 M^1, equal in length to L M of the plan. Draw M^1 O^3, which produce in the direction of F^5 making M^1 F^5 equal to K F^4, from which center continue the inner line of the pattern, as shown by m^1 i^1, which in length must equal m i of the plan. In like manner, from the same center, with radius F^2 L^3 of Fig 482, describe the arc M^1 I^1 and draw I^1 F^5. Set off on this line from i^1 a distance equal to P^1 A^3 of Fig. 480, thus establishing the center P^3. Describe the arc i^1 k, in length equal to i k of the plan. In like manner, from the same center, with the radius P^1 A^3 of Fig. 480 describe the arc I^1 K^2, in the length equal to I K of the plan. Place the straight edge against the points P^3 and K^2 and draw K^2 k, thus completing the pattern.

From inspection it is evident that the pattern might have been commenced at any other point as well as at K k of the plan. If the joint is desired upon any of the other divisions between the arcs, as L l, M m, or I i, the method of obtaining it will be so nearly the same as above narrated as not to require special description. If the joint is wanted at some point in one of the arcs of the plan, as, for example,

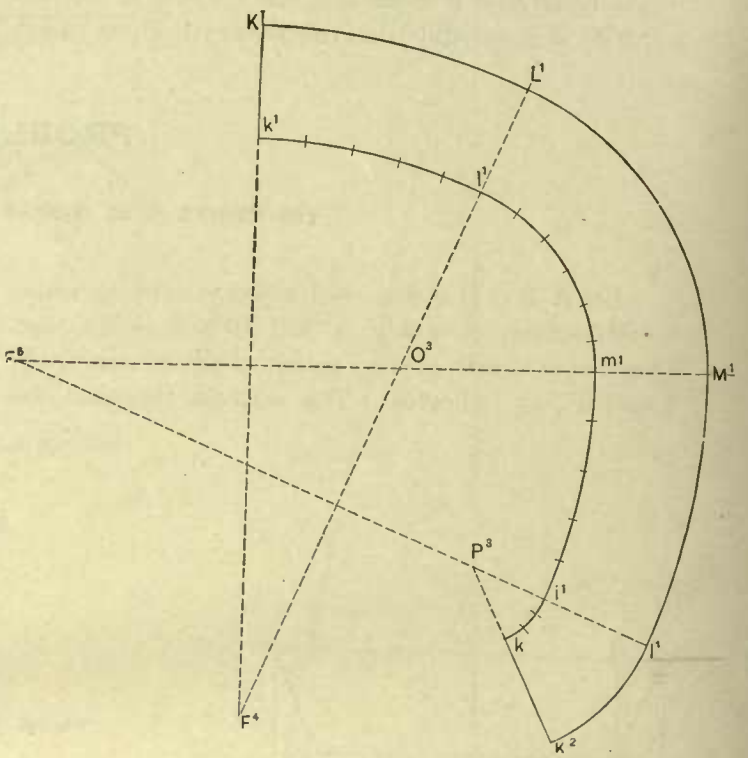


Fig. 483.—The Pattern of an Oval or Egg-Shaped Flaring Pan.

at X x, draw the line X x across the plan, producing it until it meets the center by which that arc of the plan is struck. In laying off the pattern, commence with a line corresponding to X F^1, in place of F^4 K^1, and from it lay off an arc corresponding to the portion of the arc in the plan intercepted by X x, as shown by X L l x. Proceed in other respects the same as above described until the line k K^2 is obtained, against which there must be added an arc corresponding to the amount cut from the first part of the plan by X x, as above described, or, in other words, equal to X K k x of the plan.

PROBLEM 135.

The Envelope of the Frustum of a Right Cone, the Upper Plane of Which Is Oblique to Its Axis.

In Fig. 484, let C B D E be the elevation of the required shape. Produce the sides C B and E D until they intersect at A. Then A will be the apex of the cone of which C B D E is a frustum. Draw the axis A G, which produce below the figure, and from a center lying in it draw a half plan of the article, as shown by F G H.

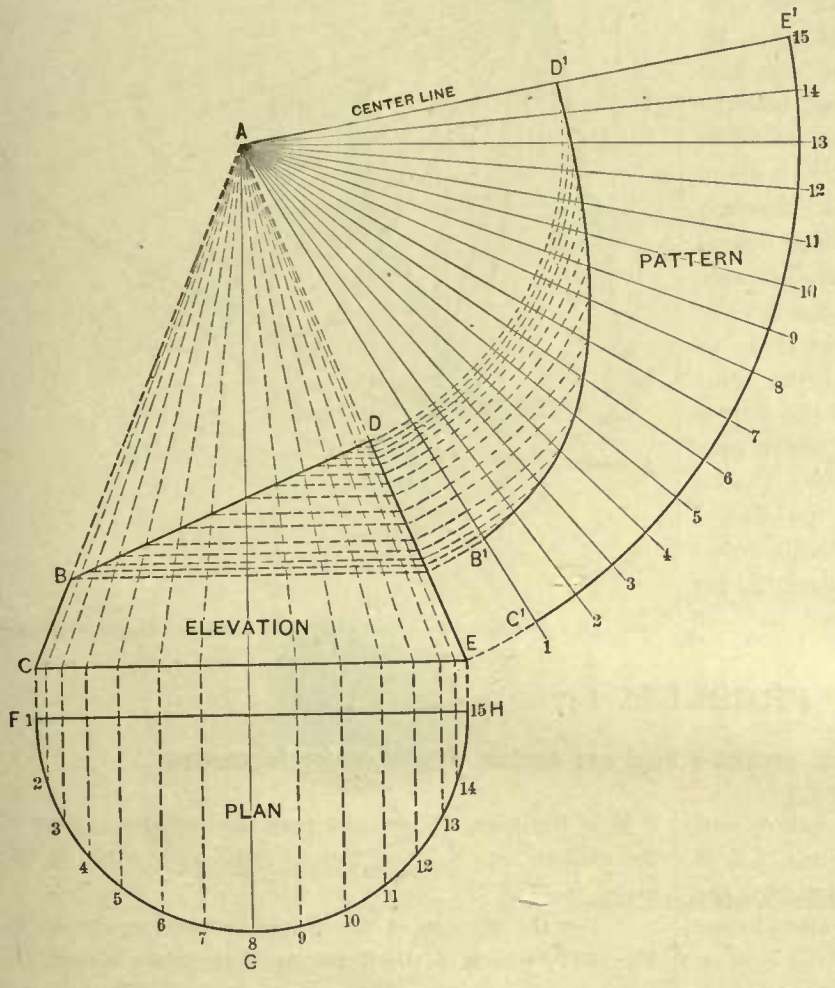


Fig. 484.—The Envelope of the Frustum of a Right Cone Whose Upper Plane is Oblique to its Axis.

Divide this plan into any number of equal parts, and from the points carry lines parallel to the axis until they cut the base line, and from there extend them in the direction of the apex until they cut the upper plane B D. Place the T-square at right angles to the axis, and, bringing it against the several points in the line B D, cut the side A E, as shown. From A as center, with A E as radius, describe the arc C' E', on which lay off a stretchout of either a half or the whole of the plan, as may be desired, in this case a half, as shown. From the extremities of this stretchout, C' and E', draw lines to the center, as C' A and E' A. Through the several points in the stretchout draw similar lines to the center A, as shown. With the point of the compasses set at A, bring the pencil to the point D in the side A E, and with that radius describe an arc, which produce until it cuts the corresponding line in the stretchout, as shown at D'. In like manner, bringing the pencil against the several points between D and E in the elevation, describe arcs cutting the corresponding measuring lines of the stretchout. Then a line traced through these intersections will form the upper line of the pattern, the pattern of the entire half being contained in C' B' D' E'.

PROBLEM 136.

The Envelope of a Right Cone Whose Base Is Oblique to Its Axis.

In Fig. 485, let G D H be the elevation of a right cone whose base is oblique to its axis, the pattern of which is required. It will be necessary first to assume any section of the cone at right angles to its axis as a

base upon which to measure its circumference. This can be taken at any point above or below the oblique base according to convenience.

Therefore at right angles to the axis D O, and through the point G, draw the line G F. Extend the axis, as shown by D B, and upon it draw a plan of the cone as it would appear when cut upon the line G F, as shown by A B C. Divide the plan into any convenient number of equal parts, and from the points thus obtained drop lines on to G F. From the apex D, through the points in G F, draw lines to the base G H. From D as center, with D G as radius, describe an arc indefinitely, on which lay off a stretchout taken from the plan A B C, all as shown by I M K. From the center D, by which the arc was struck, through the points in the stretchout, draw radial lines indefinitely, as shown. Place the blade of the T-square parallel to the line G F, and, bringing it against the several points in the base line, cut the side D H, as shown, from F to H. With one point of the compasses in D, bring the other successively to the points 1, 2, 3, 4, etc., in F H, and describe arcs, which produce until they cut the corresponding lines drawn through the stretchout, as indicated by the dotted lines. Then a line, I L K, traced through these points of intersection, as shown, will complete the required pattern.

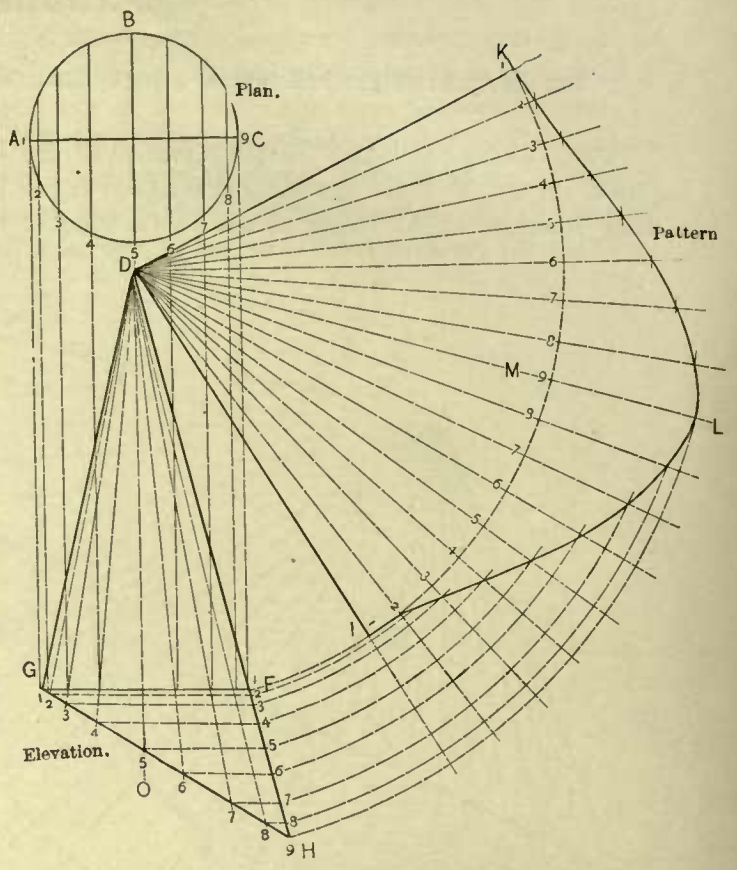


Fig. 485.—The Envelope of a Cone whose Base is Oblique to its Axis

PROBLEM 137.

A Conical Flange to Fit Around a Pipe and Against a Roof of One Inclination.

In Fig. 486 is shown, by means of elevation and plan, the general requirements of the problem. A B represents the pitch of the roof, G H K I represents the pipe passing through it, and C D F E the required flange fitting around the pipe at the line C D and against the roof at the line E F. The flange, as thus drawn, becomes a portion of the envelope of a right cone.

At any convenient distance below the elevation assume a horizontal line as a base of the cone upon which to measure its diameter, and continue the sides downward till they intersect this base line, all as shown at L M. Also continue the sides upward till they intersect at W, the apex. Below the elevation is shown a plan, and similar points in both views are connected by the lines of projection. S T represents the pipe and N O the flange. While the pipe is made to pass through the center of the cone, as may be seen by examining the base line L M in the elevation, and also P R of the plan, it does not pass through the center of the oblique cut E F in the elevation, or, what is the same, N O of the plan.

For the pattern of the flange proceed as shown in Fig. 487, which in the lettering of its parts is made to correspond with Fig. 486, just described. Divide the half plan P X R into any convenient number of parts—in this case twelve—and from each of the points thus established erect perpendiculars to the base of the cone, obtaining the points $1'$, $2'$, $3'$, etc. From these points draw lines to the apex of the cone W, cutting the oblique line E F and the top of the flange C D, as shown. Inasmuch as C D cuts the cone at right angles to its axis, the line in the pattern corresponding to it will be an arc of a circle; but with E F, which cuts the cone obliquely to its axis, the case is different, each point in it being at a different distance from the apex. Accordingly, the several points in E F, obtained by

the lines from the plan drawn to the apex W, must be transferred to one of the sides of the cone, where their distances from W can be accurately measured. Therefore from the points 0^3, 1^3, 2^3, 3^3, in E F, draw lines at right angles to the axis of the cone W X, cutting the side W M, as shown. With W as center, and with W M as radius, strike the arc P' R' indefinitely, and, in the plan P X R, all as shown by 0^3, 1^3, 2^3, 3^3, etc. From these points draw lines to the center W, as shown. With one point of the dividers set at W and the other brought successively to the points obtained in W M by the horizontal lines drawn from E F, cut the corresponding lines in the stretchout of the pattern, as indicated by the curved dotted lines. A line traced through

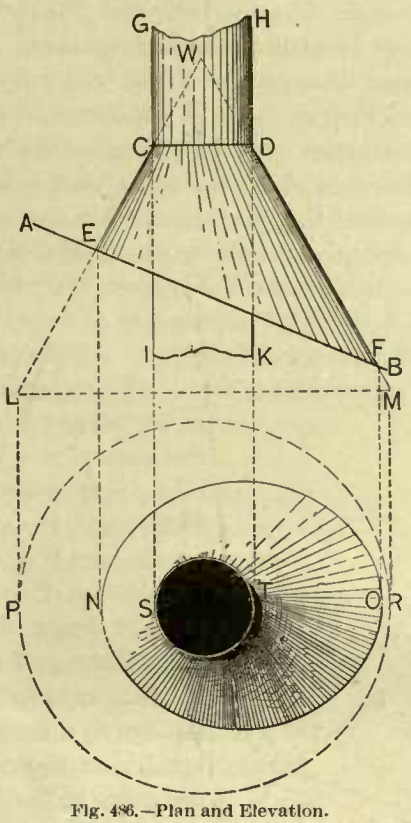


Fig. 486.—Plan and Elevation.

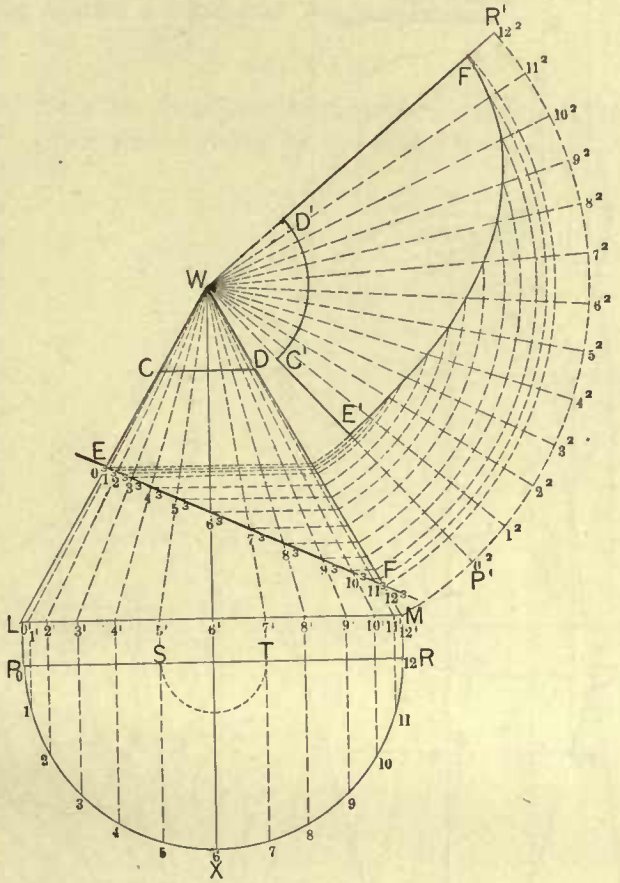


Fig. 487.—Pattern.

A Conical Flange to Fit Around a Pipe and Against a Roof of One Inclination.

with the same center and with W D as radius, strike the arc C' D' indefinitely, which will form the boundary of the pattern at the top. At any convenient distance from M draw W P', a portion of the length of which will form the boundary of one end of the pattern. On P' R', commencing with P', set off spaces equal in length and the same in number as the divisions these points, as E' F', will represent the lower side of the pattern. As but one-half of the plan has been used in laying out the stretchout, the pattern C' E' F' D' thus obtained is but one-half of the piece required. It can be doubled so that the seam can be made to come through the short side at C E, or through the long side at D F, at pleasure.

PROBLEM 138.

The Pattern for a Cracker Boat.

Let E F H G, in Fig. 488, be the side elevation, A B C D E the end, and I K J L the plan of a dish sometimes called a cracker boat or bread tray. The sides of the dish are parts of the frustum of a right cone. To the plan have been added the circles showing the complete frustums of which the sides are a part,

L and K being the centers, all of which will appear clear from an inspection of the drawing, and below is further shown a side view of this frustum. While in the plan the top and bottom of the sides have been shown parallel, in the side view the top appears curved at C, the cut producing which curve being shown by B C of the end view.

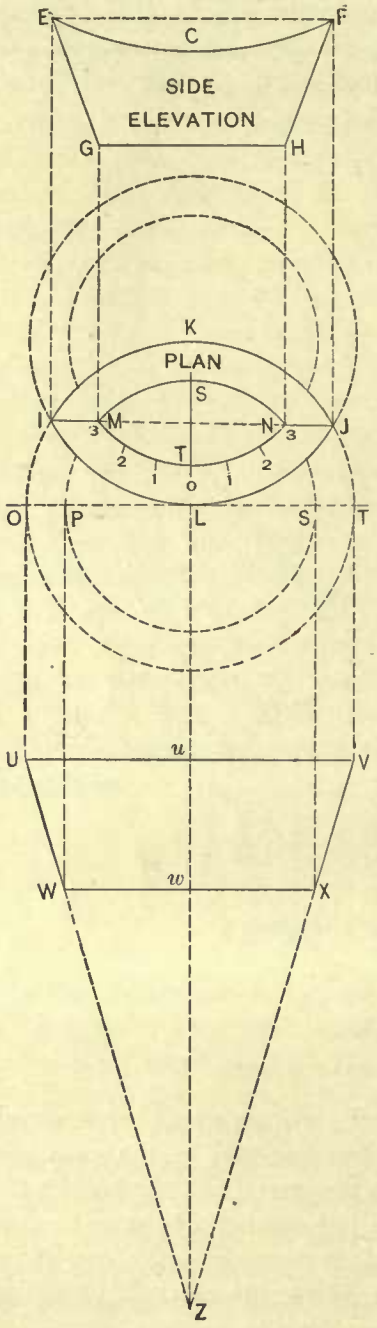


Fig. 488.—Plan and Elevations.

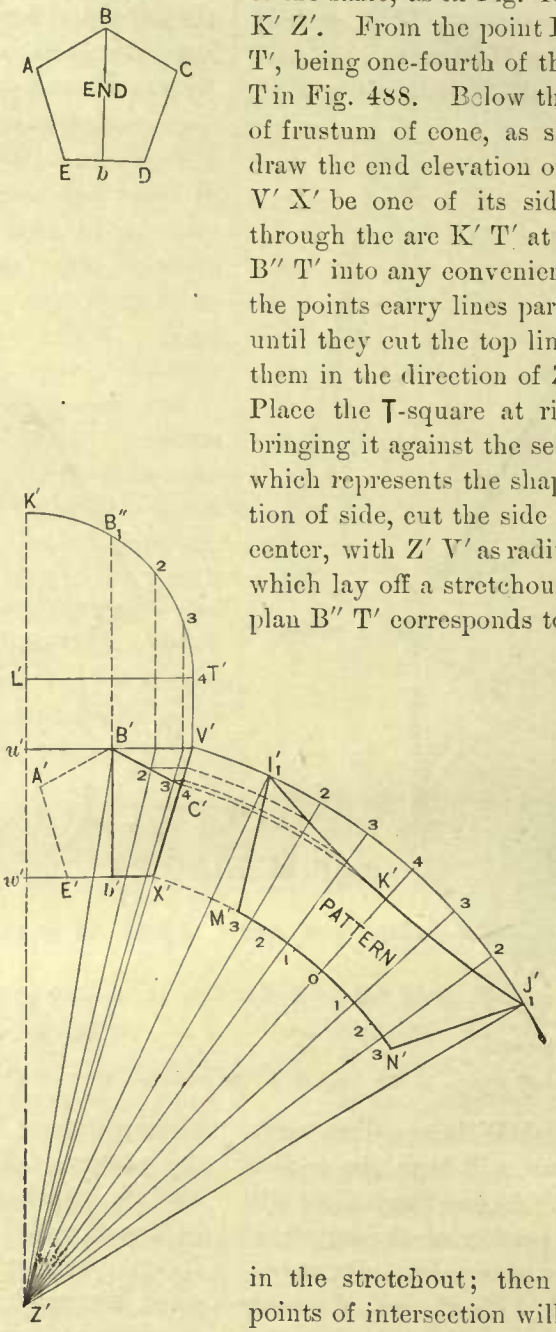


Fig. 489.—Pattern.

The Pattern for a Cracker Boat.

Extend the sides U W and V X of the frustum until they meet at Z, which is the apex of the completed cone. Before the pattern can be described it will be necessary to draw a half elevation of the cone U V Z, showing the end view of the tray in its relation to the same, as in Fig. 489. Draw any center line, as K′ Z′. From the point L′, as center, strike the arc K′ T′, being one-fourth of the plan of top, as shown by K T in Fig. 488. Below the plan of top draw one-half of frustum of cone, as shown by *u′* V′ X′ *w′*, in which draw the end elevation of boat A′ B′ C′ X′ E′, letting V′ X′ be one of its sides, and extend the line *b′* B′ through the arc K′ T′ at B″. Divide the part of plan B″ T′ into any convenient number of parts, and from the points carry lines parallel to the center line or axis until they cut the top line *u′* V′, and from there extend them in the direction of Z′ until they cut the line B′ C′. Place the T-square at right angles to the axis, and, bringing it against the several points in the line B′ C′, which represents the shape shown by E C F in elevation of side, cut the side V′ X′, as shown. From Z′ as center, with Z′ V′ as radius, describe the arc I′ J′, upon which lay off a stretchout of plan. As the part of the plan B″ T′ corresponds to B′ C′, which shows one-half of one side of boat, and as this part of plan is divided into three parts, six of these parts are spaced off on the arc I′ J and numbered from 1 to 4, and 4 to 1, 4 being the center line. Through these points in the stretchout draw measuring lines to the center Z′, as shown. With one point of the compasses set at Z′, bring the pencil point up to the several points between V′ and C′ in the elevation, and describe arcs cutting measuring lines of corresponding numbers in the stretchout; then a line traced through these points of intersection will form the line I′ K′ J′, showing the upper line of the pattern for one side of the boat.

To obtain the bottom line of the pattern, with Z′ as center and radius Z′ X′, describe the arc M′ N′. Divide the plan of bottom of boat, as M T N in Fig. 488, into any convenient number of equal parts, in this case six, three on each side of the center T, and starting from the center line 4 of pattern, space off three spaces each way on the arc M′ N′, thus establish-

ing the points M′ and N′ of pattern, corresponding to the points M and N of plan. By drawing the lines M′ I′ and N′ J′ the pattern for one side of the boat, shown by E F H G in elevation, is completed.

PROBLEM 139.

Pattern for the Frustum of a Cone Fitting Against a Surface of Two Inclinations.

In Fig. 490, let A B C D represent the frustum of a cone, the base of which is to be so cut as to make it fit against a roof of two inclinations, as indicated by P R D. Continue the lines of the sides of the cone A B and D C upward until they meet in the point X, which is the apex of the complete cone. Through the apex of the cone draw the line X R, representing the axis of the cone, meeting the ridge of the roof in the point R, and continuing downward in the direction of Y, as shown. At any convenient distance below A D draw a horizontal line, G H, as a base, and immediately below it draw a plan of the same, as shown by E S F Y.

Subdivide this plan into any convenient number of spaces, as indicated by the small figures 0, 1, 2, 3, etc. From the points thus established carry lines vertically until they cut the base of the cone G H, and from this line carry them in the direction of the apex X until they cut the line of the given roof. From the points established in the roof line A R draw lines at right angles to the axis of the cone X Y, continuing them until they strike the side of the cone A B. From X as center, with X G as radius, describe the arc G K, upon which lay off a stretchout of the plan.

As the pattern really consists of four equal parts or quarters, the divisions of the plan have been numbered from 0 to 4 and from 4 to 0 alternating, the points 0 representing the lowest and the points 4 the highest points of each quarter. Therefore in numbering the points of the stretchout G K, any point can be assumed as a beginning which is deemed the best place for the joint (in this case 4), numbering from 4 to 0 and reversing each time, all as shown. From these points established in the arc G K draw lines to the apex X. Then, with X as center, and with radii corresponding to the points already established in the side B G of the cone, strike arcs as shown by the dotted lines, cutting measuring lines of corresponding number. Then a line traced through the points of intersection, as shown by O L, will

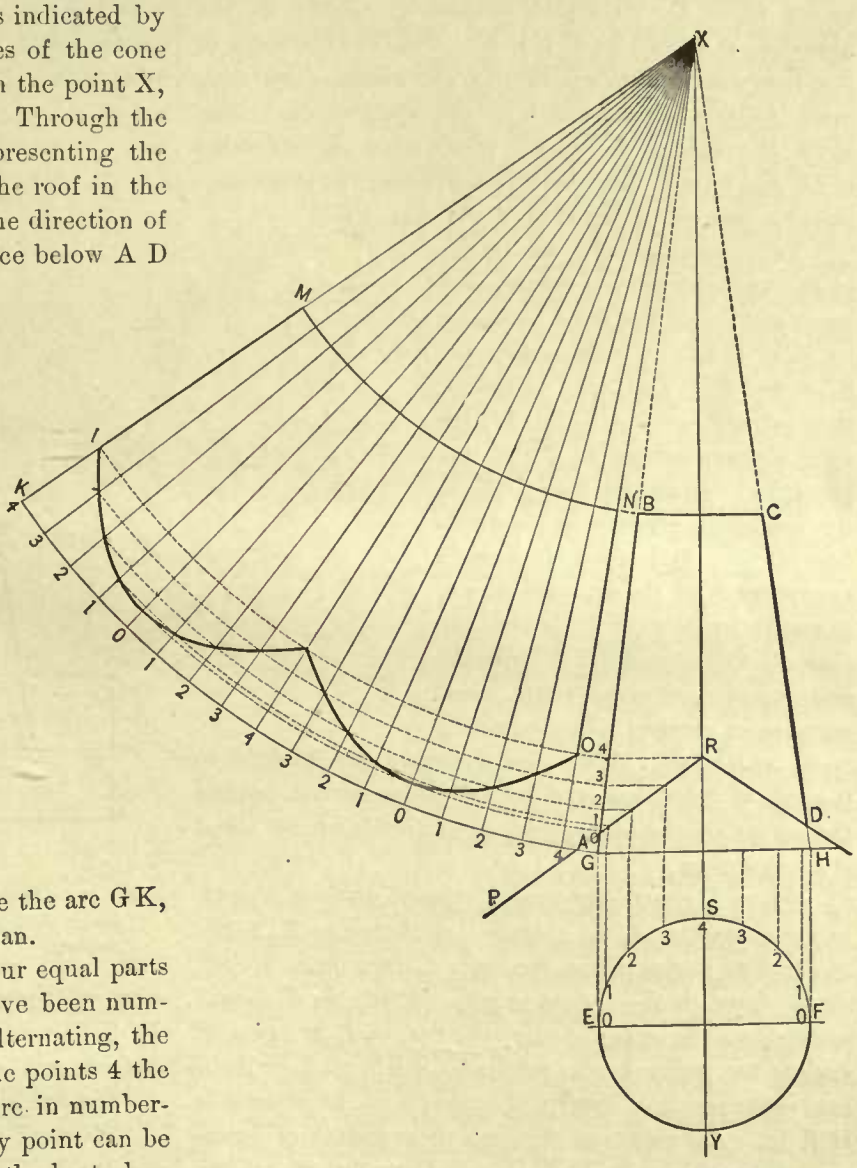


Fig. 490.—Pattern for the Frustum of a Cone Fitting Against a Surface of Two Inclinations.

be the shape of the pattern at the bottom and O N M L will constitute the entire pattern of the frustum of a cone adapted to set over the ridge of a roof, as indicated in the elevation.

PROBLEM 140.

The Pattern of a Frustum of a Cone Intersected at its Lower End by a Cylinder, Their Axes Intersecting at Right Angles.

Let S P R T in Fig. 491 be the elevation of the cylinder, and *a* G K H *b* the elevation of the frustum. Draw the axis of the cylinder, A B, which prolong, as shown by C D, on which construct a profile of the cylinder, as shown by C E D F. Produce the sides of the frustum, as shown in the elevation, until they meet in the point L, which is the apex of the cone. Draw the axis L K, which produce in the direction of O, and at any convenient point upon the same construct a plan of the frustum at its top, *a b*.

In connection with the profile of the cylinder draw a corresponding elevation of the cone, as shown by K' *a*' *b*' K². Produce the sides K' *a*' and K² *b*' until they intersect, thus obtaining the point L', the apex corresponding to L of the elevation. Draw the axis L' E, as shown, which produce in the direction of N', and upon it draw a second plan of the frustum at *a b*, as shown by M' O' N'. Divide the plans M O N and M' O' N' into the same number of equal parts, commencing at corresponding points in each, as shown. With the T-square set parallel to the axis of the cones, and brought successively against the points in the plans, drop lines to the lines *a b* and *a*' *b*', as shown.

From L' draw lines through the points in *a*' *b*', cutting the profile of the cylinder, as shown in K' E K², and in like manner from the apex L draw lines indefinitely through the points in *a b*. Place the T-square parallel to the sides of the cylinder, and, bringing it against the points in the profile K' E K² just described, cut corresponding lines in the elevation, as shown at H K G. A line traced through these points of intersection, as shown by H K G, will form the miter line between the two pieces as it appears in elevation.

This miter line is not necessary in obtaining the pattern, but the method of obtaining it is here introduced merely to show how it may be done, should it be desired under similar circumstances in any other case. The development of the pattern in this case could be most easily accomplished by using L' as a center from which to strike ares from the various points on the line *a*' K'. The same result is accomplished, however, by continuing the lines drawn from K' E K² until they meet the side *a* G of the cone prolonged, as shown from G to Z. Thus *a* Z becomes in all respects the same as *a*' K'.

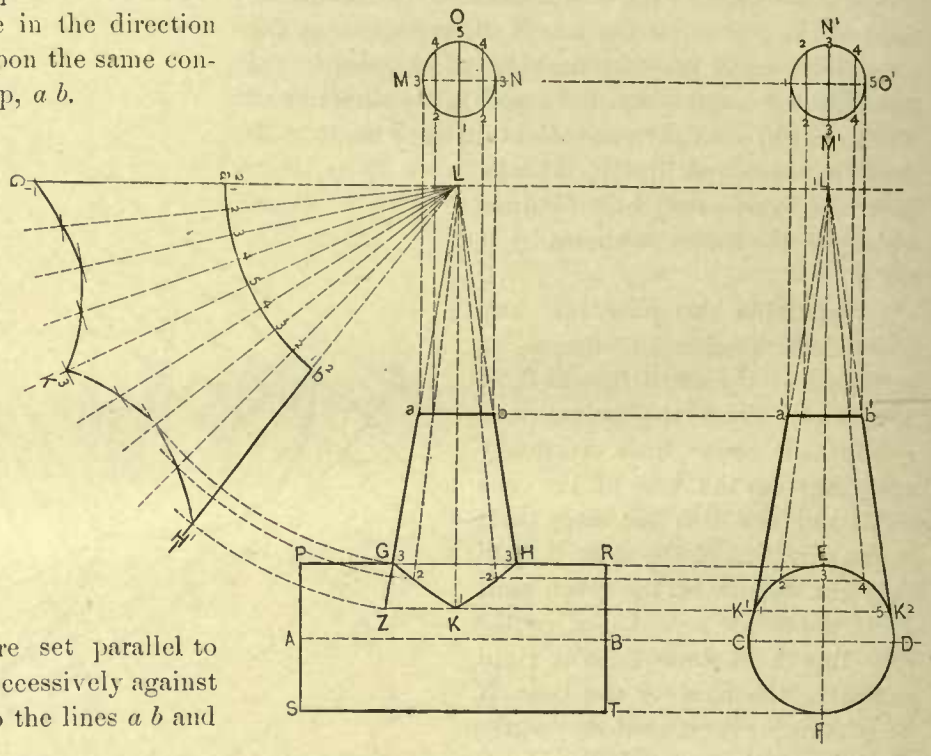


Fig. 491.—The Pattern of a Frustum of a Cone Intersected at Its Lower End by a Cylinder, Their Axes Intersecting at Right Angles.

From L as center, and with radius L *a*, describe the are *b*² *a*², upon which lay off a stretchout of the plan M O N of the frustum. Through each of the points in this stretchout draw lines indefinitely, radiating from L, as shown. Number the points in the

stretchout a^3 b^3 corresponding to the numbers in the profile, commencing with the point occurring where it is desired to have the seam. Set the compasses to L Z as radius, and, with L as center, describe an arc cutting the corresponding lines drawn through the stretchout, as shown by 1, 5 and 1. In like manner reduce the radius to the second point in G Z, and describe an arc cutting 2, 4, 4 and 2. Also bring the pencil to the third point and cut the lines corresponding to it in the same way. Then a line traced through the points thus obtained, as shown by H^1 K^3 G^1, will be the pattern of the frustum.

PROBLEM 141.

The Pattern for a Conical Boss.

The principles and conditions in this problem are exactly the same as those in the one immediately preceding (that is, the frustum of a cone mitering against a cylinder, their axis being at right angles), but its proportions are so different that it is here introduced as showing that the same application of principles often produces results so widely differing in appearance as to be scarcely recognizable.

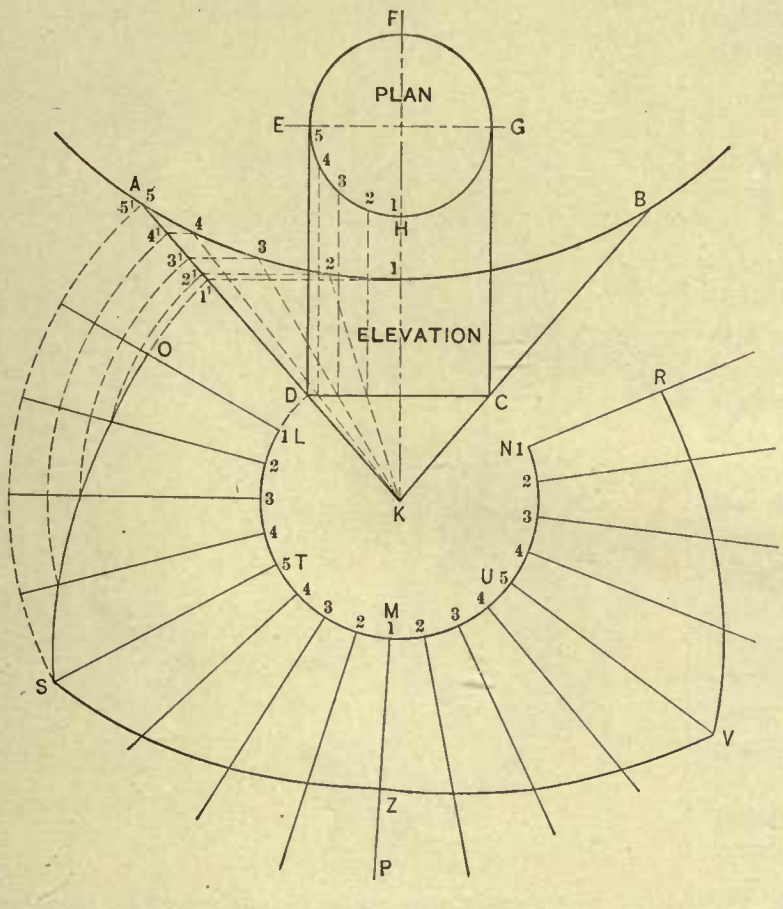


Fig. 492.—The Pattern for a Conical Boss.

Let A B C D of Fig. 492 represent the elevation of the boss that is required to fit against the cylindrical can, a portion of the plan of which is shown by the arc A B. The plan at the smaller end of the boss is represented by E F G H. Continue the lines A D and B C until they intersect at K, which is the apex of the cone of which the boss is a frustum. An inspection of the elevation will show that it is only necessary to describe one-fourth of the pattern, the remaining parts being duplicates. Divide one-quarter of the plan into any convenient number of parts, in the present instance four, as shown by the points in H E. Drop lines from these points to the base D C, as shown. Draw lines from K through the points in the base until they intersect the arc at A B, which represents the body of the can. These points can be numbered to correspond with the points in the plan from which they are derived. At right angles to the line F K draw lines from the points on A B until they strike the line A K, where their true distances from K can be measured. With K as a center, and K D as radius, strike the arc L M N, equal in length to the circumference of plan.

If the whole pattern of boss is to be described from measurements derived from elevation it will be necessary to reverse the order of the numbers for each quarter, as shown. From K draw lines extending outwardly through these points, as indicated by the small figures. With K as center, draw an arc from the point 1′ until it intersects radial lines 1 drawn from K, as shown at O, Z and R. In the same manner draw an arc from 2′ to lines 2, &c., as shown. A line traced through these points will produce the desired patterns, as shown by L O S Z V R N.

PROBLEM 142.

Pattern for the Lip of a Sheet Metal Pitcher.

Let A B C D of Fig. 493 represent the side elevation of a pitcher top having the same flare all around, and E F G H the plan at the base. By producing the lines A D and B C until they intersect in the point K, the apex of the cone of which the pitcher top is a section will be obtained. Divide one-half of the plan into any convenient number of equal spaces, as shown by the points in G H E. From these points drop lines to the base D C, as indicated. Then draw radial lines from K, cutting the points in D C, and producing them until they intersect the curved line representing the top of the pitcher, otherwise an irregular cut through the cone, as shown by A B. For convenience in subsequent operations, number these points to correspond with the numbering of the points in the plan from which they are derived.

Place the T-square at right angles to the axial line of the cone H K, and, bringing it against the several points in A B, cut the line D A, as shown in the diagram. By this means there will be obtained in the line K A the length of radii which will describe arcs corresponding to points in the top line of the lip A B. With K as center and K D as radius, describe the arc L M N, which in length make equal to the circumference of the plan by stepping off on it spaces equal to the spaces originally established in the plan, all as indicated by the small figures. From K through each of the points in L M N thus established draw radial lines, extending outwardly indefinitely, as shown. Then with K as center and K^0, $K,^1$ K^2, etc., as radii, strike ares, which produce until they intersect radial lines of corresponding number just drawn, all as shown in the diagram. Then a line traced through the points thus obtained will be the required pattern, all as shown by L O P R N M.

The method above described is a strictly mathematical rule for obtaining such shapes when a design embodying the necessary curve at the top is at hand. As by the nature of the problem, this part of the pattern does not require to be fitted or joined to any other piece, it would be much easier to obtain, by the foregoing method, the principal points in the outside curve of the pattern and finish by drawing the remainder to suit the taste of the designer. In other words, after the arc L M N has been drawn and stepped off into spaces, draw radial lines from K through the points representing the highest and the lowest parts required in the top curve, as 0.5 and 12, upon which lines the required lengths can be set off. Then these points can be connected by any curve suitable for the purpose.

The principle involved in the foregoing is exactly the same as that of a hip or sitz bath given in the following problem, the difference in the finished article being a matter of size and shape and not of principle. Thus the sides could be made less flaring by placing the point K much further away from the base line, the hight A D could be increased and the curve A B could be altered to one more desirable; but the various steps necessary to perform the task would remain exactly the same.

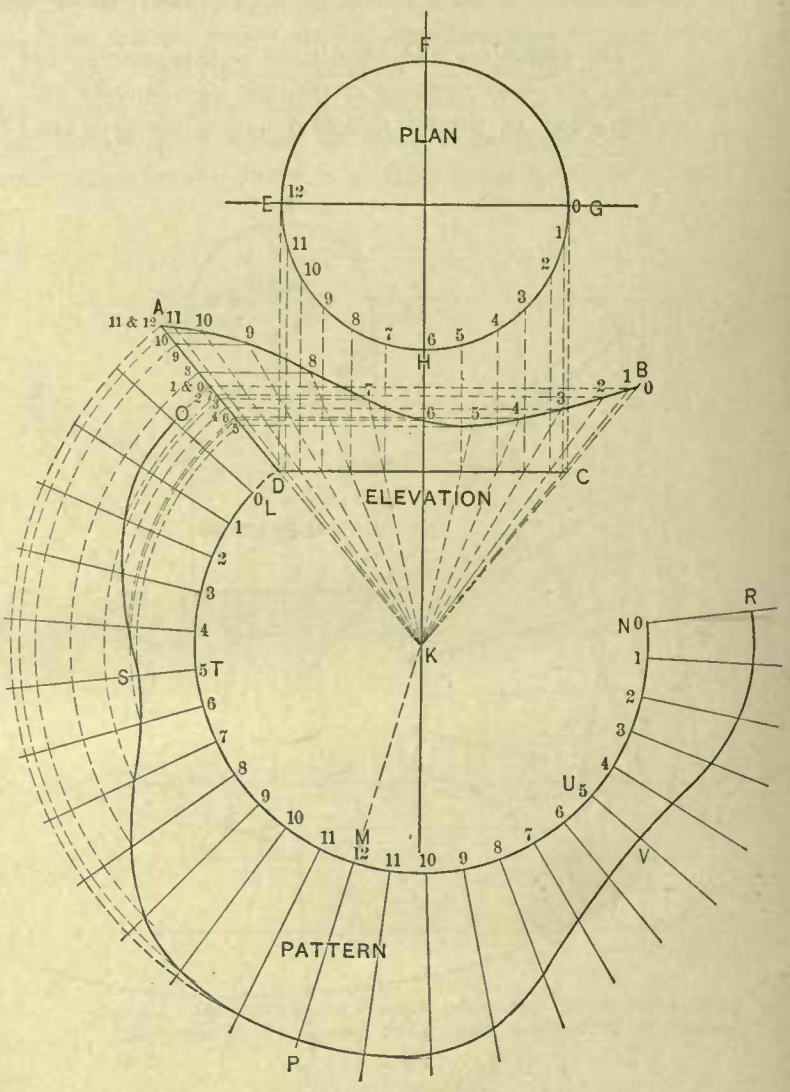


Fig. 493.—Pattern for the Lip of a Sheet Metal Pitcher.

PROBLEM 143.

Pattern for a Hip Bath of Regular Flare.

Let C B D E, in Fig. 494, be the elevation of the body of a hip bath having an equal amount of flare on all sides, the plan of which is a circle. In describing the pattern for the body it will be considered as a section of a right cone, the plane C E being at right angles to the axis and the base being represented by the curved line B D, as shown. The sides E D and C B can be extended until they meet at A. Then A will be the apex of a cone of which C B D E is a frustum having an irregular base B D.

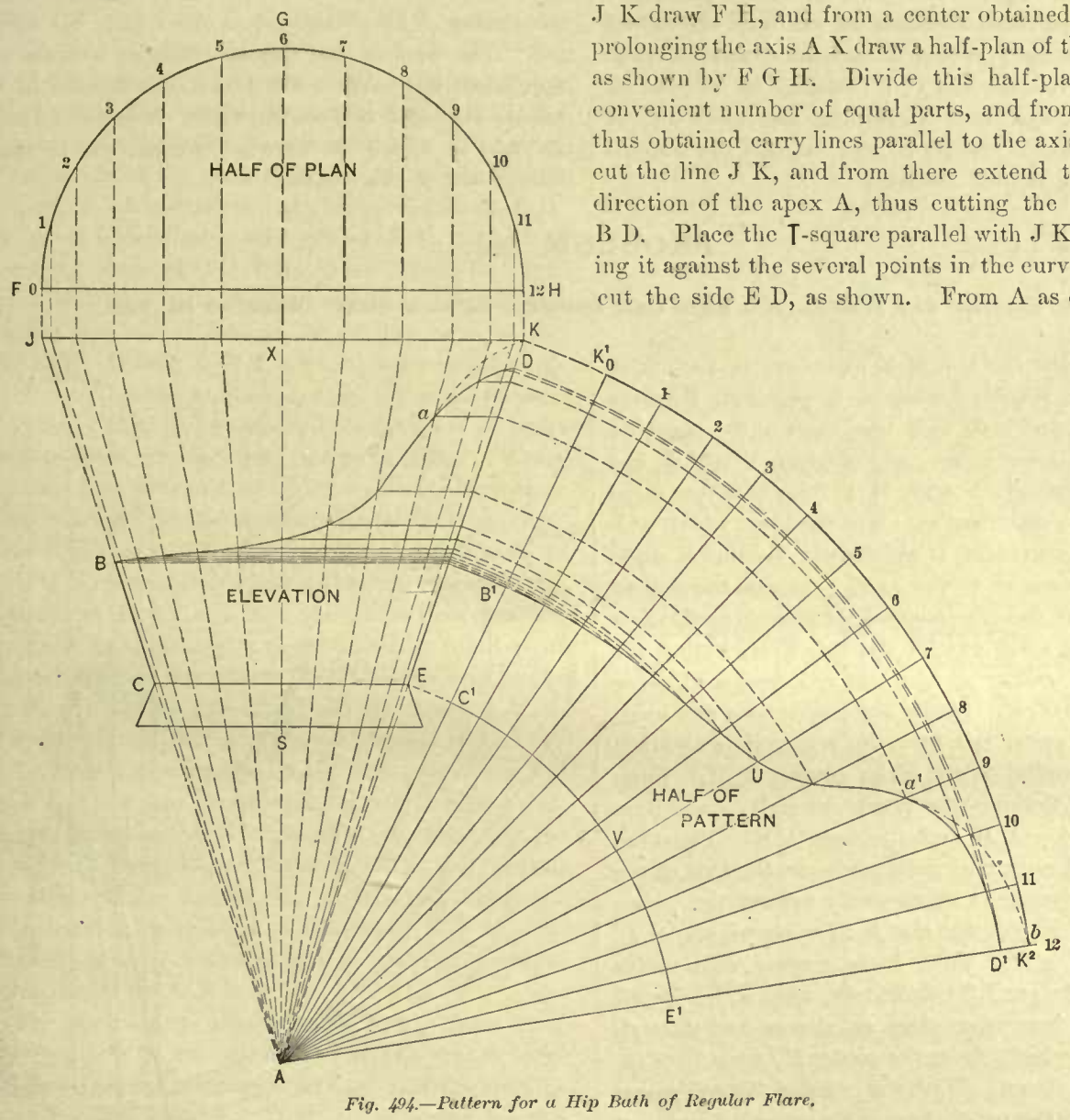


Fig. 494.—Pattern for a Hip Bath of Regular Flare.

At any convenient distance above D draw J K parallel to C E to be used as a regular base upon which to measure the circumference of the cone. Parallel to J K draw F H, and from a center obtained on F H by prolonging the axis A X draw a half-plan of the frustum, as shown by F G H. Divide this half-plan into any convenient number of equal parts, and from the points thus obtained carry lines parallel to the axis until they cut the line J K, and from there extend them in the direction of the apex A, thus cutting the curved line B D. Place the T-square parallel with J K, and bringing it against the several points in the curved line B D, cut the side E D, as shown. From A as center, with A K as radius, describe the arc K^1 K^2, on which lay off a stretchout of either one-half or the whole of the plan, as may be desired. In this case a half is shown. From the extremities of this stretchout, as K^1 and K^2, draw lines to the center, as K^1 A and K^2 A, and from the several points in the stretchout draw similar lines, as shown by 1, 2, etc. With one point of the dividers

set at A bring the pencil point to the point D in the side A K, and with that radius describe an arc, which produce until it cuts the corresponding line 12 in the stretchout, as shown at D^1. In like manner, bringing the pencil point up to the several points between D and E in the elevation, describe arcs cutting lines of corresponding numbers in the stretchout. Then a line traced through these intersections will form the upper line of the pattern. From A as center, with A E as radius, describe the arc C^1 E^1, cutting A K^1 and A K^2, as shown by C^1 and E^1, forming the lower line of pattern. Then C^1 B^1 D^1 E^1 will be half the pattern for the side of the hip bath.

As a feature of design, the form produced in the pattern by a curved line B D drawn arbitrarily may not be entirely satisfactory. If, for instance, that part of the pattern lying between lines 9 and 12 should not appear as desired, it can be modified upon the pattern at will, as this edge of the pattern is not required to fit any other form. Such a modification is shown by the dotted lines a^1 K^2 of the pattern and a K of the elevation. The foot of the tub is a simple frustum of a right cone, the pattern for which is obtained in the manner described in Problem 123. Different forms of bathtubs in which the flare is irregular will be found in Section 3 of this chapter.

PROBLEM 144.

The Envelope of a Frustum of a Right Cone Contained Between Planes Oblique to Its Axis.

In Fig. 495, let F L M K represent the section of the cone the pattern for which is required. Produce the sides F L and K M until they meet in the point N, which is the apex of the cone of which F L M K is a frustum. Through N draw N E. bisecting the angle L N M and constituting the axis of the cone, which produce in the direction of D indefinitely. From K draw K H at right angles to the axis. At any convenient distance above the cone construct a plan or profile as it would appear when cut on the line K H, letting the center of the profile fall upon the axis produced, all as shown by A D C B. Divide the profile into any number of equal parts, and from the points thus obtained draw lines parallel to the axis, cutting K H. From the apex N, through the points in K H, draw lines cutting the top L M and the base F K. Place the blade of the T-square at right angles to the axis of the cone, and, bringing it successively against the points in L M and F K, cut the side N F, as shown above L, and from H to F. From N as center, with radius N H, strike the arc T S indefinitely, upon which lay off a stretchout from the plan, as shown, and through the points of which, from the center N, draw lines indefinitely, as shown. With the point of the compasses still at N, and the pencil brought successively against the points in the side from H to F, describe arcs, which produce until they cut corresponding lines drawn through the stretchout. Then a line traced through these points of intersection, as shown by T U S, will form the lower line of pattern. In like manner draw arcs by radii corresponding to the points in the side at L, which produce also until they intersect corresponding lines drawn through the stretchout. A line traced through these points, as R P O, will be the upper line of the pattern sought.

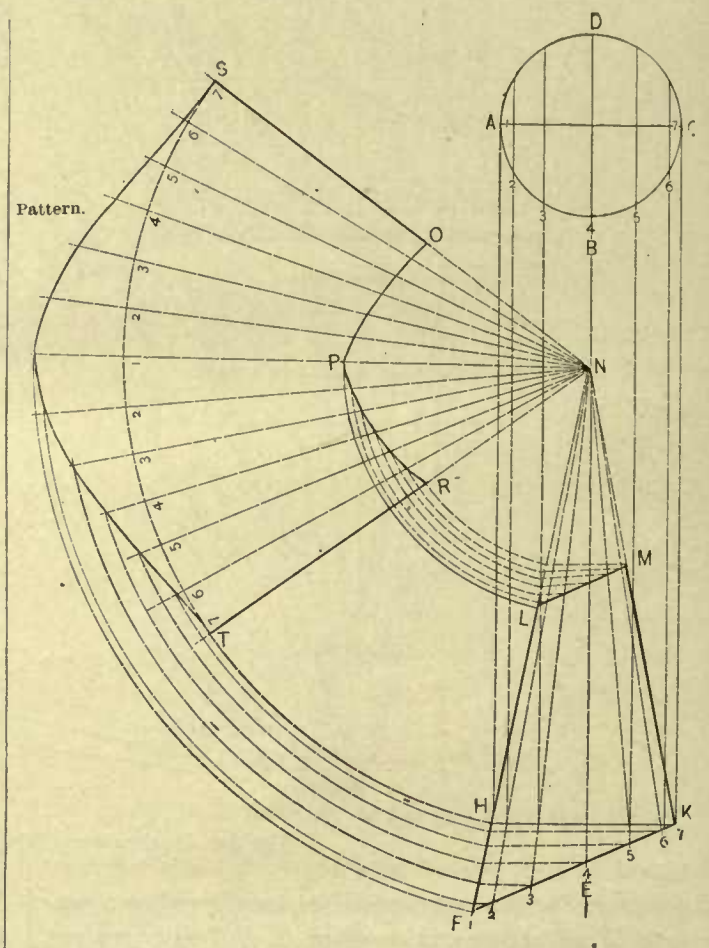


Fig. 495.—The Envelope of a Frustum of a Right Cone Contained between Planes Oblique to its Axis.

PROBLEM 145.

The Pattern of a Cone Intersected by a Cylinder at Its Upper End, Their Axes Crossing at Right Angles.

In the plan, Fig. 496, let A B C D F represent a frustum of the cone B C G, B H C being the half profile of cone at its base and A D J the plan of the cylinder. In line with the cylinder in plan draw the elevation, as shown by R S T U. With the T-square placed parallel to the sides of the cylinder, carry a line from the point G in plan to any convenient point, as G′ of elevation. At right angles to G G′ draw G′ Q indefinitely, and extend B C through Q G′, cutting same at O. With O as center, and E C of plan as radius, describe the semicircle L Q M, representing one-half of the profile of the cone at the larger end. Divide L Q M into any convenient number of equal parts, as indicated by the small figures. From the points thus obtained carry lines at right angles to L M, cutting that line as indicated. From the points thus obtained in L M carry lines to the apex G′, as indicated by the dotted lines in the engraving. Divide B H C into the same number of equal parts as was L Q M, numbering them to correspond with the elevation, as shown, and from the points thus obtained carry lines at right angles to B C, cutting that line as indicated. From the points in B C carry lines to the apex G, cutting the plan of cylinder as shown. With the blade of the T-square placed parallel with G G′, and brought successively against the points thus established in the plan of the cylinder, cut lines of corresponding number drawn from the points in L M to the apex G′, as indicated from K to N, and extend these lines to the line M G′. A line traced through these points of intersection, as shown by K P N, represents the intersection of cone with cylinder in elevation, as shown by A F D in plan.

For the pattern proceed as follows: From G′ as center, with G′ M as radius, describe an arc, as indicated by *l o m*, and, starting from *l*, step off the stretchout of the half profile L Q M, as indicated by the small figures. If the entire pattern is required in one piece extend the arc *l o m*, and from *m* set off a duplicate of *l o m*, numbering the points in inverse order. From the points thus obtained draw radial lines to G′, as indicated. Then with G′ as center, and with radii corresponding to the distance from G′ to the points established in M G′, describe arcs, producing them until they cut lines of corresponding number drawn from G′. A line traced through these points of intersection, as shown by *k p n*, will with *l o m* give

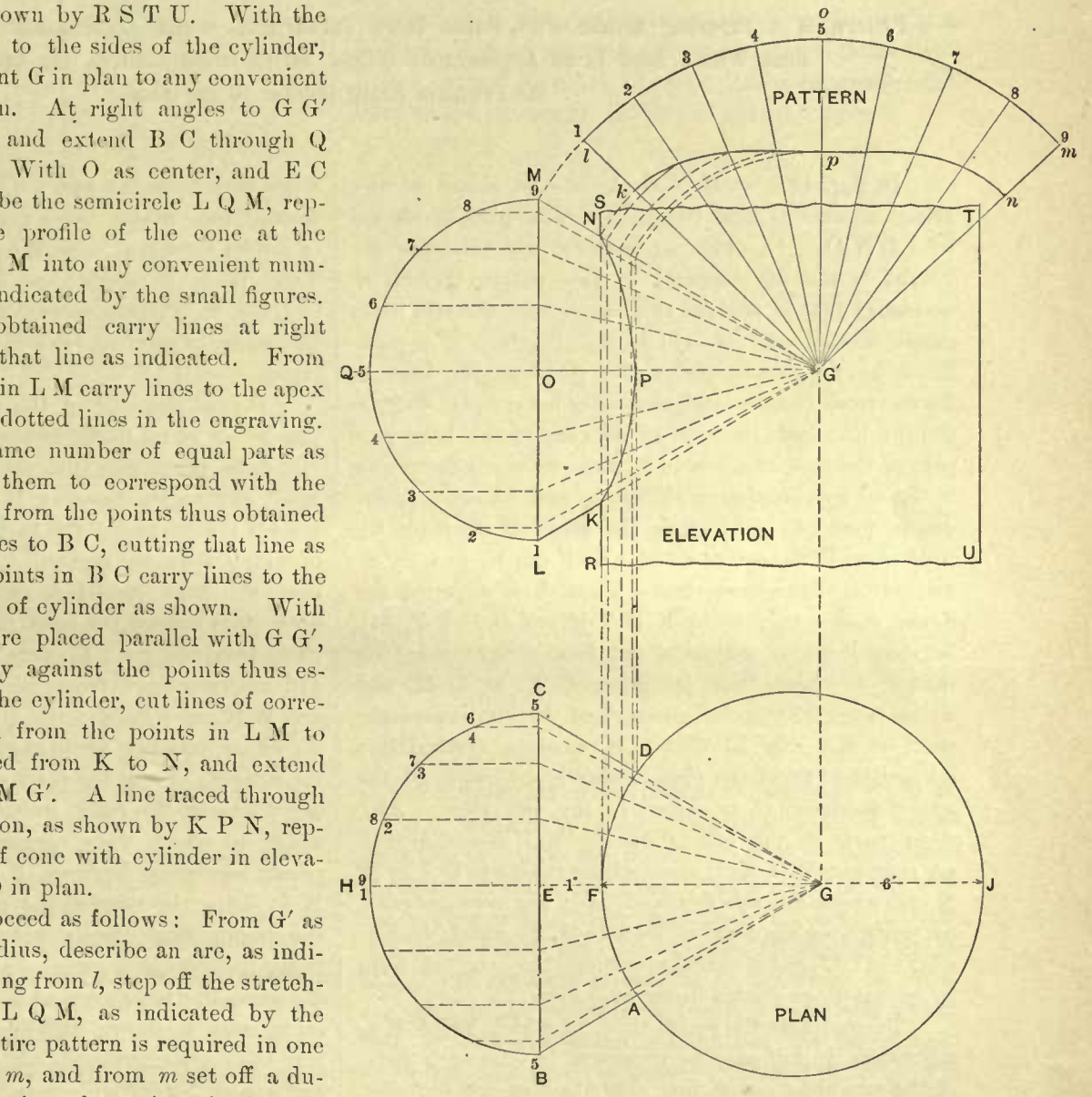


Fig. 496.—Pattern of a Cone Intersected by a Cylinder at its Upper End.

the pattern of part of article shown in elevation by L M N P K.

It will be easily seen that the pattern might have

been obtained directly from the plan without the trouble of drawing the elevation, as in Problems 141, 142 and 143. Should it be desirable, however, to cut an opening in the side of the cylinder to fit the frustum of the cone, the hights of all points in the perimeter of such opening must be obtained from the line N P K of the elevation, while width of the opening upon lines corresponding to these points must be measured from F toward D or A upon the circumference of the cylinder.

PROBLEM 146.

Pattern of a Tapering Article with Equal Flare Throughout, which Corresponds to the Frustum of a Cone Whose Base Is an Approximate Ellipse Struck from Centers, the Upper Plane of the Frustum Being Oblique to the Axis.

In Fig. 497, let H F G A be the shape of the article as seen in side elevation. The plan is shown by I L N O. In order to indicate the principle involved in the development of this shape, it will be necessary first to analyze the figure and ascertain the shape of the solid of which this frustum is a part. Since by the conditions of the problem the base is drawn from centers and the sides have equal flare, it follows that each arc used in the plan of the base is a part of the base of a complete cone whose diameter can be found by completing the circle and whose altitude can be found by continuing the slant of its sides till they meet at the apex, all of which can be seen by an inspection of the engraving. Thus those parts of the figure shown in plan by K U T M and R U T P may be considered as segments cut from a right cone, the radius of whose base is either O K or L R, and whose apex E is to be ascertained by continuing the slant of the side L^2 C^1 till it meets a vertical line erected from O^1 of the plan, which is the center of the arc of the base, all as shown in the end view. Also those parts of the plan shown by K U R and M T P are segments of a right cone whose radius is U I or T N and whose altitude is found, as in the previous case, by continuing the slant of its side G A (which is parallel to C^1 L^2) till it meets a vertical line erected from its center T, as shown in the side view.

To complete the solid, then, of which F G A H is a frustum, it will only be necessary to take such parts of the complete cones just described as are included between the lines of the plan and place them together, each in its proper place upon the plan. The resulting figure would then have the appearance shown by H D C B A when seen from the side, and that of O^2 C^1 L^2 when seen from the end. The lines of projection connecting the various views together with the similarity of letters used will show the correspondence of parts. This figure is made use of in the second part of Chapter V, Principles of Pattern Cutting, to which the reader is referred for a further explanation of principles.

Divide one-half of the plan into any convenient number of equal parts, as shown by the small figures, and from the points thus established carry lines vertically, cutting the base line H A, and thence carry them toward the apexes of the various cones from the bases of which they are derived. That is, from the points upon the base line H A derived from the arc K M draw lines toward the apex E, and from the points derived from the arc I K carry lines toward the apex D, and in like manner from the points derived from the arc M N carry lines in the direction of the apex B, all of which produce until they cut the top line F G of the article. From the points in F G thus established carry lines to the right, cutting the slant lines of the cones to which they correspond. Thus, from the points occurring between F and *f* draw lines cutting B A, being the slant of the small cone, as shown by the points immediately below W. In like manner, from the points between *g* and G carry lines cutting the same line, as shown at G. The slant line of the large cone is shown only in end elevation, and therefore the lines corresponding to the points between *f* and *g* must be carried across until they meet the line B^1 L^2.

Commence the pattern by taking any convenient point, as E^1, for center, and E^1 L^2 as radius, and strike the arc L^2 S indefinitely. Upon this arc, commencing

at any convenient point, as K⁴, set off that part of the stretchout of the plan corresponding to the base of the larger cone, as shown by the points 5 to 13 in the plan, and as indicated by corresponding points from K⁴ to M² in the arc. From the points thus established draw lines indefinitely in the direction of the center E¹, as shown. From E¹ as center, with radii corresponding to the distance from E¹ to points 5 to 13 inclusive, established in the line B¹ L² already described, cut corresponding radial lines just drawn, and through the points of intersection thus established draw a line, all as shown by f^1 g^1. Next take A B of the side elevation as radius, and, setting one foot of the compasses in the point K⁴ of the arc, establish the point D¹ in the line K⁴ E¹, and in like manner, from M², with the same radius, establish the point B² in the line M² E¹, which will be the centers from which to describe those parts of the patterns derived from the smaller cones. From D¹ and B¹ as centers, with radius B A, strike arcs from K⁴ and M², respectively, as shown by K⁴ I² and M² N¹, upon which set off those parts of the stretchout corresponding to the smaller cones, as shown by the arcs K I and M N of the plan. From the points thus established, being 5 to 1 and 13 to 17, inclusive, draw radial lines to the centers D¹ and B², as shown.

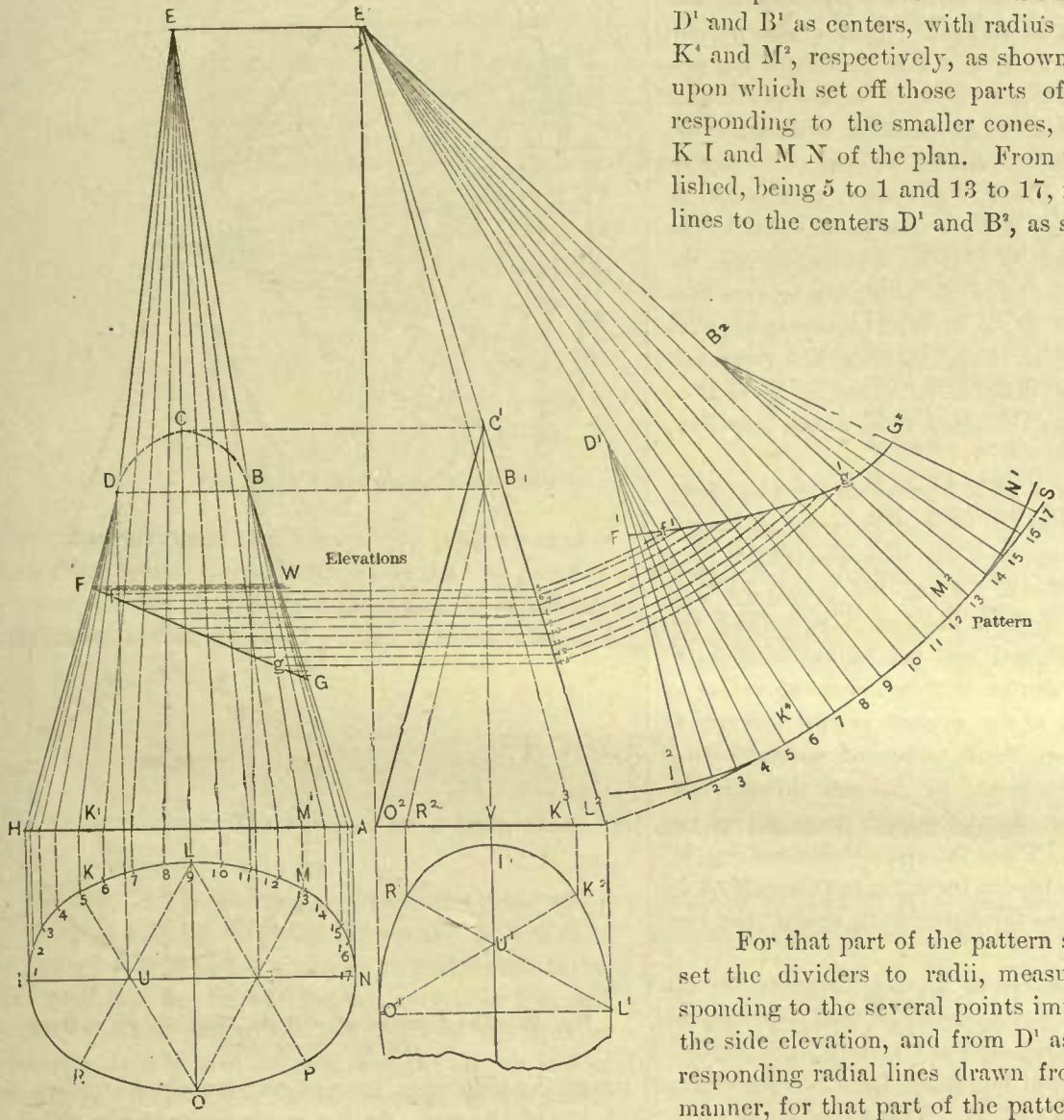


Fig. 497.—Pattern of the Frustum of a Cone, the Base of which is an Approximate Ellipse Struck from Centers, the Upper Plane of the Frustum being Oblique to the Axis.

For that part of the pattern shown from F¹ to f^1, set the dividers to radii, measuring from B, corresponding to the several points immediately below W of the side elevation, and from D¹ as center cut the corresponding radial lines drawn from the arc. In like manner, for that part of the pattern shown from G¹ to g^1, set the dividers to radii measured from B, corresponding to the points in the line B A at G, with which, from B² as center, strike arcs cutting the corresponding measuring lines, as shown. Then F¹ G¹ N¹ I² will be one-half of the pattern sought—in other words, the part corresponding to I K L M N of the plan. The whole pattern may be completed by adding to it a duplicate of itself.

PROBLEM 147.

The Envelope of a Right Cone, Cut by a Plane Parallel to Its Axis.

Let B A F in Fig. 498 be a right cone, from which a section is to be cut, as shown by the line C D in the elevation. Let G L H K be the plan of the cone in which the line of the cut is shown by D^1 D^2. For the pattern proceed as follows: Divide that portion of the plan corresponding to the section to be cut off, as shown by D^1 G D^2, into as many spaces as are necessary to give accuracy to the pattern, and divide the remainder of the plan into spaces convenient for laying off the stretchout. From A as center, with radius A B, describe an arc, as M N, which make equal to the stretchout of the plan G L H K, dividing it into the same spaces as employed in the plan, taking care that its middle portion, D^3 D^4, is divided to correspond with D^1 D^2 of the plan. From the points in M N corresponding to that portion of the plan indicated by D^1 G D^2—namely, 8 to 16 inclusive—draw lines to the center A, as shown.

From points of the same number in the plan carry lines vertically, cutting the base of the cone, as shown from B to D, and thence continue them toward the apex A, cutting C D, as shown. From the points in C D carry lines at right angles to the axis A E cutting the side of the cone, as shown by the points between C and B. From A as center, with radii corresponding to the distances from A to the several points between C and B, cut lines drawn from points of corresponding number in the stretchout, to A, and through the points of intersection thus obtained trace a line, as shown by D^3 C^2 D^4. Then the space indicated by D^3 C^2 D^4 is the shape to be cut from the envelope M A N of the cone to produce the shape to fit against the line C D in the elevation.

To obtain the pattern of a piece necessary to fill the opening D^2 C^2 D^4 in the envelope, and represented by C D of the elevation, draw any vertical line, through which draw a number of horizontal lines corresponding in hight to the points in C D. The width of the piece upon each of these lines may be found by measuring

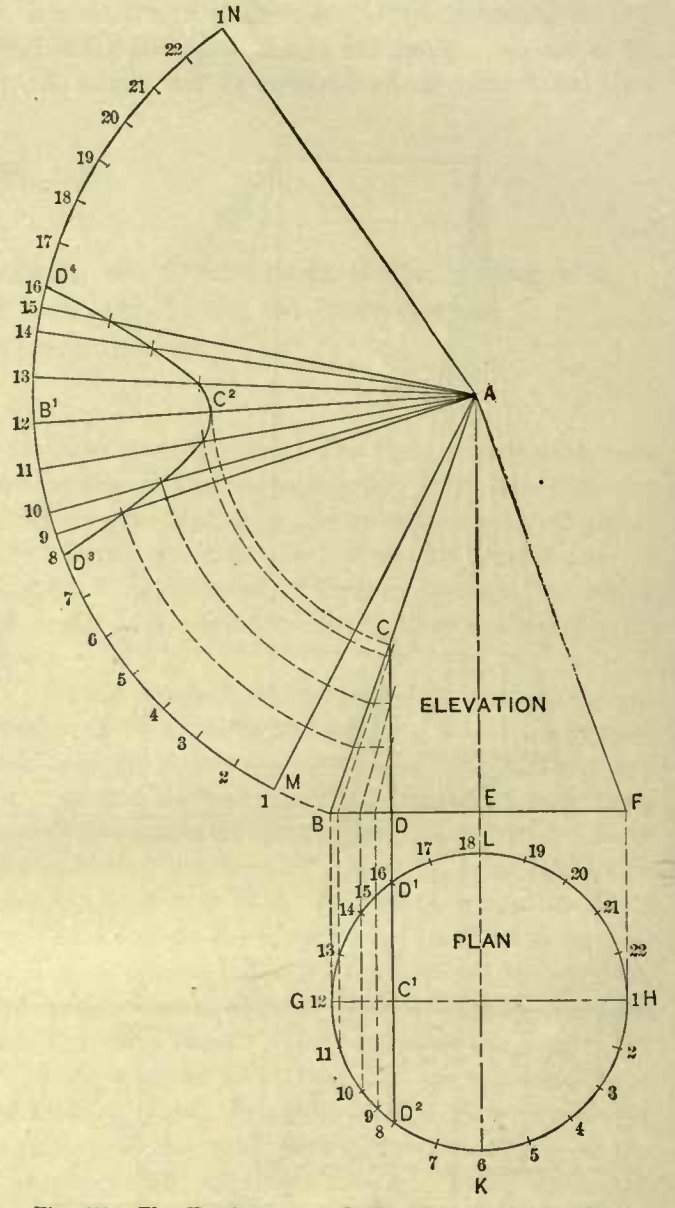


Fig. 498.—The Envelope of a Right Cone Cut by a Plane Parallel to its Axis.

across the plan upon lines of corresponding number, as 11 13, 10 14, etc. Such a section is properly called a hyperbola (see Def. 113, Chap. I).

PROBLEM 148.

The Pattern for a Scale Scoop, Having Both Ends Alike.

In Fig. 499, let A B C D represent the side elevation of a scale scoop,-of a style in quite general use, and E F H G a section of the same as it would appear cut upon the line B D, or, what is the same,

so far as concerns the development of the patterns, an end elevation of the scoop. The curved line A B C, representing the top of the article, may be drawn at will, being, in this case, a free-hand curve. For the patterns proceed as follows: From the center K, by which the profile of the section or end elevation is

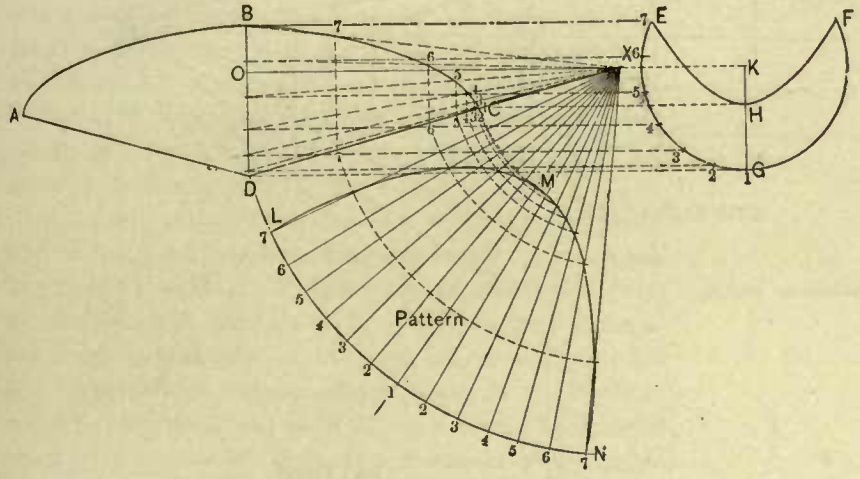


Fig. 499.—The Pattern for a Scale Scoop.

drawn, draw a horizontal line, which produce until it meets the center line of the scoop in the point O. Produce the line of the side D C until it meets the line just drawn in the point X. Then X is the apex and X O the axis of a cone, a portion of the envelope of which each half of the scoop may be supposed to be.

Divide one-half of the profile, as shown in end elevation by E G, into any convenient number of spaces, and from the points thus obtained carry lines horizontally, cutting the line B D, as shown, and thence carry lines to the point X, cutting the top B C, as shown. With X D as radius, and from X as center, describe an arc, as shown by L N, upon which lay off the stretchout of the scoop, as shown in end elevation. From the points in L N thus obtained draw lines to the center X, as shown. From the points in B C drop lines at right angles to O X, cutting the side D C, as shown. With X as center, and radii corresponding to each of the several points between D and C, describe arcs, which produce until they cut radial lines of corresponding numbers drawn from points in the arc L N to the center X. Then a line traced through the points thus obtained, as shown by L M N, will be the profile of the pattern of one-half of the required article.

PROBLEM 149.

The Patterns for a Scale Scoop, One End of Which Is Funnel Shaped.

In Fig. 500 is shown a side view of a scale scoop by which it will be seen that the portion A B G H of the funnel-shaped end is a simple cylinder and, therefore, need not be further noticed here. In Fig. 501 are shown a side and an end elevation of the tapering portions. It will also be seen that the part D E F of the side view is similar in all respects to the article treated in the preceding problem, and the pattern shown in connection with the same is obtained by exactly the same method as that there described and need not, therefore, be repeated.

An inspection of the side elevation will show that the part G B C D F is a section of a cone of which I is the apex, H F the base and H′ C″ F′ the plan of the base, and that this cone is cut by the lines B G and C D. To obtain the pattern of this part, first divide F′ C″ and C″ H′ of end elevation into any convenient number of parts, and from the points thus ob-

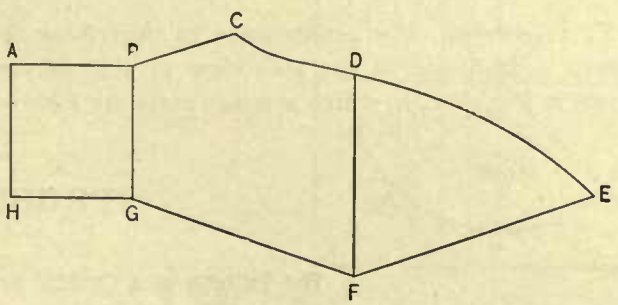


Fig. 500.—Scale Scoop, One End of which is Funnel Shaped.

tained carry lines cutting the miter line H F, as shown. From the points in H F carry lines to the

apex I, cutting the curved line C D, as shown. From the points in C D drop perpendiculars cutting the sides

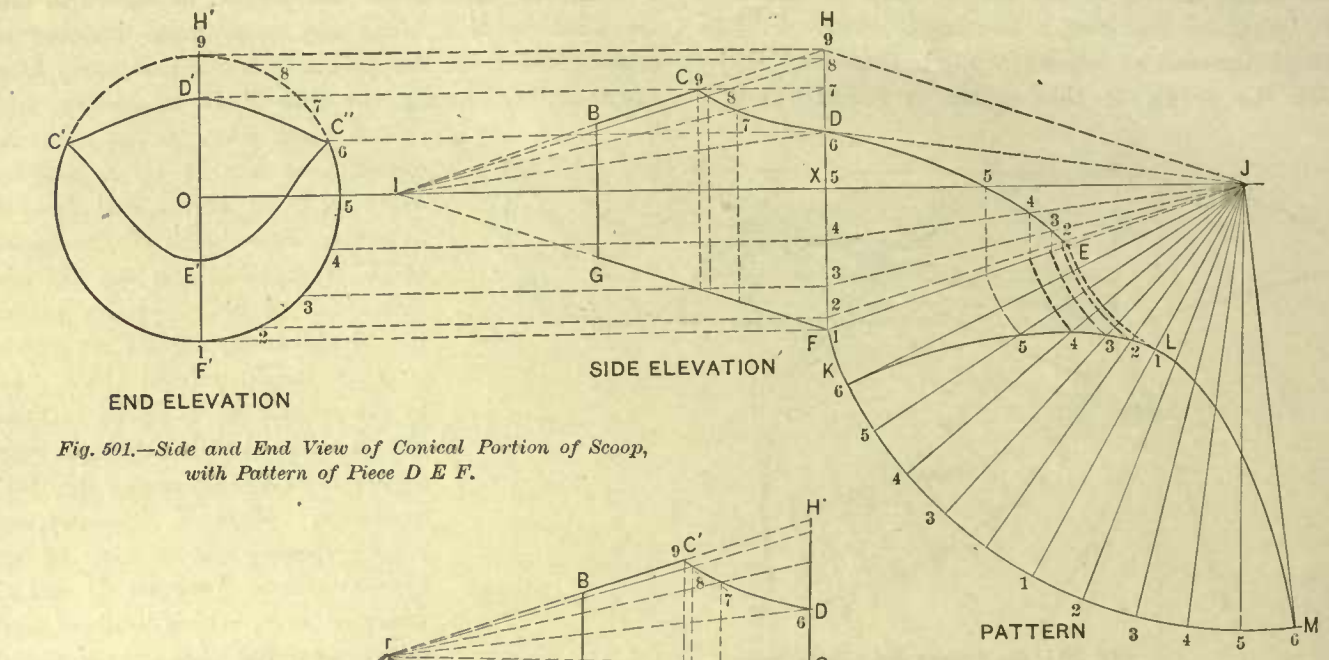


Fig. 501.—Side and End View of Conical Portion of Scoop, with Pattern of Piece D E F.

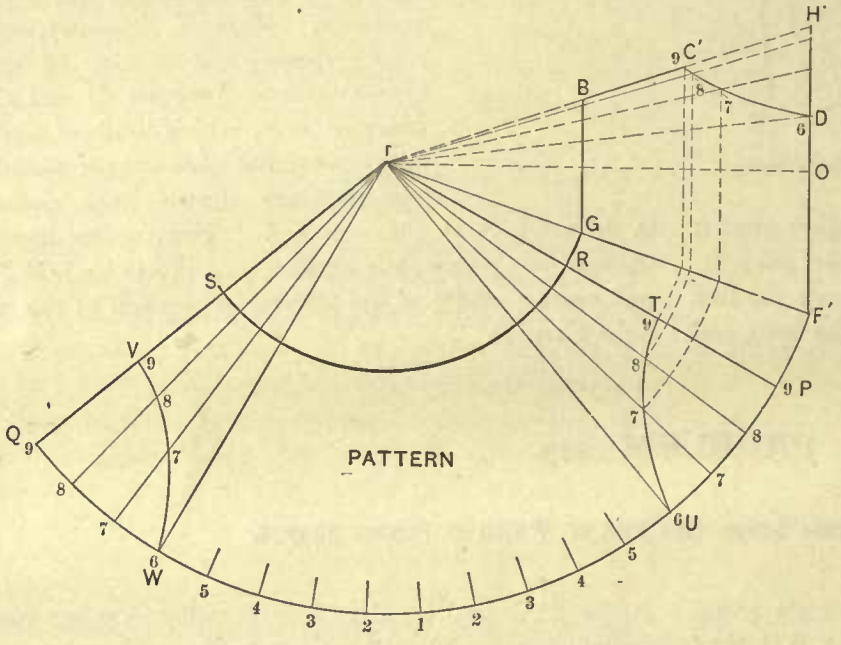


Fig. 502.—Pattern of Piece B C D F G of Fig. 500.

G F, as shown. For convenience in describing the pattern a duplicate of the side view of this part is shown in Fig. 502, in which similar parts are lettered the same as in Fig. 501. With I of Fig. 502 as center, and I G and I F as radii, describe the arcs R S and P Q. Upon P Q lay out twice the stretchout of H′ C″ F′ of Fig. 501, if the pattern is desired in one piece. Thus the stretchout of H′ C″ is represented by P U and Q W, from the points in which draw lines to the center I. From I as center, and radii corresponding to the distance from I to each of the various points in G F, describe arcs cutting lines of similar numbers. Trace lines through the points thus obtained, as shown by T U, V W. The R T U W V S is the pattern for part of scoop shown in side elevation by B C D F G.

PROBLEM 150.

The Pattern of a Conical Spire Mitering upon Four Gables.

Let E I O B in Fig. 503 be the elevation of a pinnacle having four equal gables, down upon which a conical spire is required to be mitered, as shown. Produce the sides of the spire until they meet in the apex D. Also continue the side E F downward to any convenient point below the junction between the spire

and the gables, as shown by H, which point may be considered the base of a cone of which the spire is a part. Let V K L M be the plan of the gables. The diagonal lines V L and M K represent the angles or valleys between the gables, while R S and T U represent the ridges of the gables over which the spire is to be fitted. Through the point H in the elevation draw a line to the center of the cone and at right angles to its axis, as shown by H C. This will represent the half diameter or radius of the cone at its base. With radius C H, and from center A^2 of the plan, describe a circle, as shown, which will represent the plan of the cone at its base.

At any convenient distance from the elevation, and to one side, project a diagonal section corresponding to the line M A^2 in the plan, as follows: From all the points in the side of the pinnacle draw horizontal lines indefinitely to the left, which will establish the hights of the corresponding points in the section. From any vertical line, as D^1 A^1, as a center line set off upon the horizontal lines the distances as measured upon the line M A^2 of the plan. Thus make B^1 A^1 equal to M A^2 and C^1 H^1 equal to A^2 5, the radius of the cone at its base. The point F^1 represents the hight of the crossing of the two ridges of the gables, therefore a line drawn from F^1 to B^1 will represent one of the valleys between the gables. Draw H^1 D^1, the side of the cone. Its intersection with the line of the valley at G will then represent the hight of the lowest points of the spire between the gables, and a line projected from this point back into the elevation, as shown, will locate those points in that view.

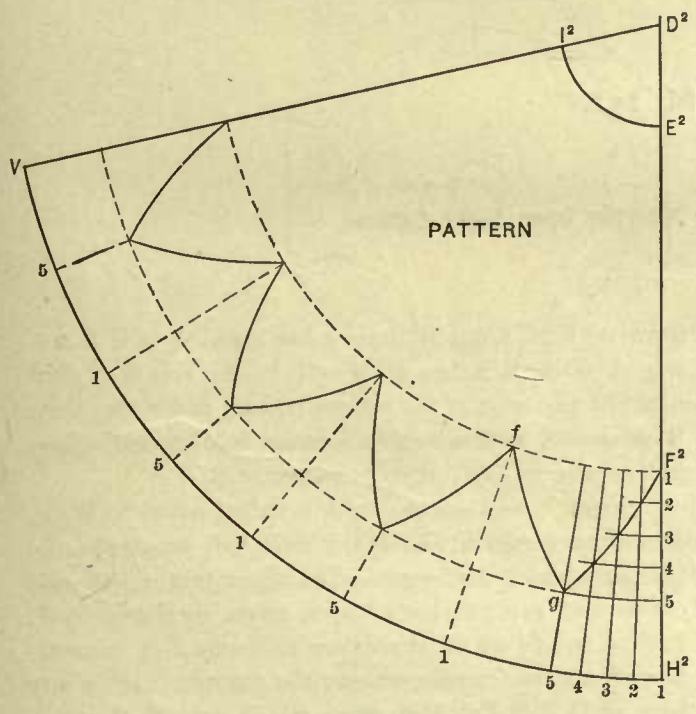


Fig. 504.—Pattern.

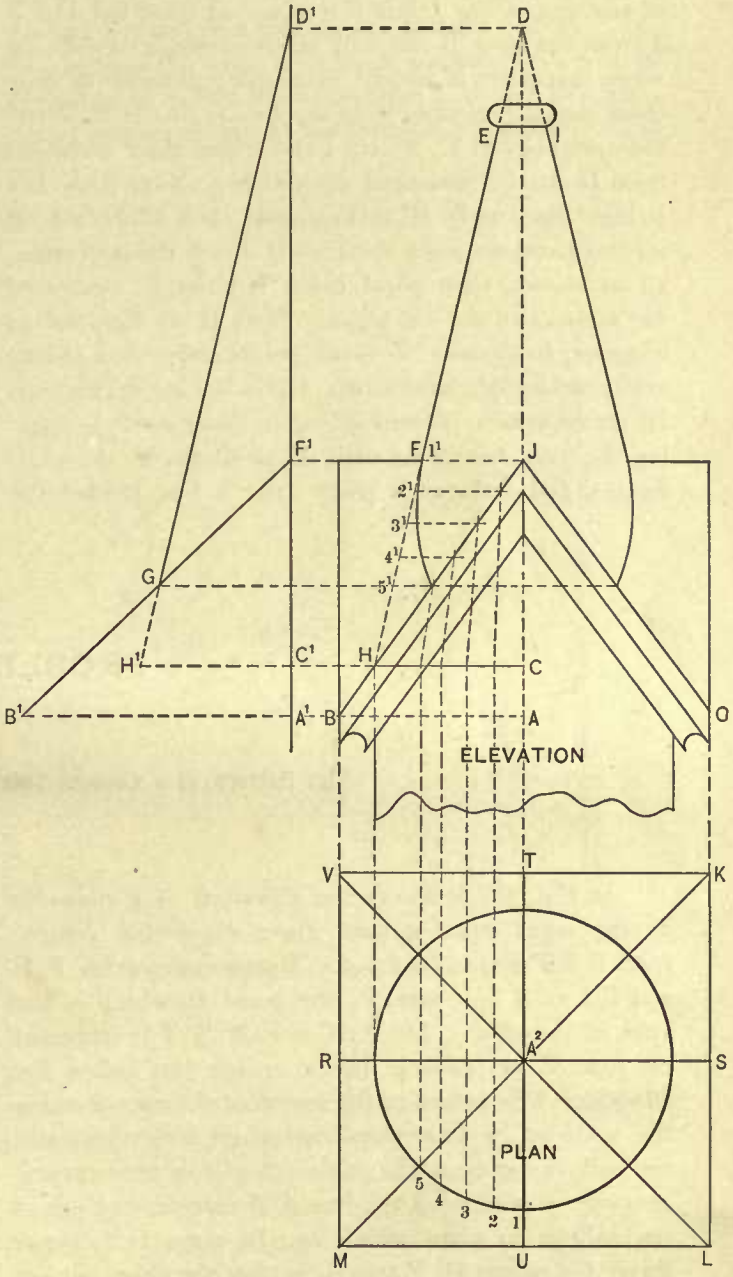


Fig. 503.—Plan, Elevation and Diagonal Section.

The Pattern of a Conical Spire Mitering Upon Four Gables.

To describe the pattern, first divide one-eighth of the plan of the cone, choosing the one which miters with the gable shown in the elevation, into any number of equal spaces, as shown by the small figures. From these points carry lines vertically cutting the base of the cone H C, as shown, and thence toward the apex D, cutting the line B J of the gable, against which this part of the cone is to miter. As the true distance of any one of the points just obtained upon the line B J from the apex D can only be measured on a drawing when that point is shown in profile, proceed to drop these points horizontally to the profile line D H, where they are marked 1', 2', etc., and where their distances from D can be measured accurately. Next draw any straight line, as D^2 H^2 of Fig. 504, upon which set off all the distances upon the line D H of the elevation, all as shown, each point being lettered or numbered the same as in the elevation. With D^2 of Fig. 504 as a center, from each of these points draw arcs indefinitely to the left, as shown. Upon the arc drawn from H^2 set off spaces corresponding to those used in spacing the plan, beginning with H^2, as shown by the small figures, and from each point draw a line toward the center D^2 cutting arcs of corresponding number drawn from the line F^2 H^2. A line traced through the points of intersection (g to F^2) will give the shape of the bottom of the cone to fit against the side of one of the gables, or one-eighth of the complete pattern.

By repeating the space 1 5 upon the arc drawn from H^2 seven times additional, as marked by the points 1 and 5, the point V will be reached, from which a line drawn to D^2 will complete the envelope of the cone. From the points marked 1 and 5 draw lines toward D^2 intersecting the arcs of corresponding number. This will locate all of the highest and lowest points of the pattern, after which the miter cut from g to F^2 can be transferred by any convenient means, as shown from g to f, and so on, reversing it each time, as shown. In the case of a spire of very tall and slender proportions it will be sufficiently accurate for practical purposes to draw the lines g F^2 and g f straight. But the broader the cone becomes at its base the more curved will the line g F^2 become. With a radius equal to D E of Fig. 503 describe the arc E^2 I^2, as shown, which will complete the pattern.

PROBLEM 151.

The Pattern of a Conical Spire Mitering Upon Eight Gables.

In Fig. 505 is shown the elevation of a pinnacle having eight equal gables, upon which the conical spire E F P I is to be fitted. Produce the sides F E and P I until they meet in the point D, which is the apex of the spire. Let A H^1 S K M N^1 T U represent the plan of the pinnacle drawn in line just below the elevation. To ascertain the length of the cone forming the spire at its longest points, where it terminates in the valleys between the gables, it will be necessary to construct a section on the line A B representing one of the valleys in plan, which can be done as follows: From the points D, F and H in the elevation project lines horizontally to the left, which intersect with any vertical line, as D^1 B^1, representing the center line of spire in the section. Upon the line drawn from H set off from B^1 a distance equal to A B of the plan and draw A^1 F^1. From D^1 draw a line parallel to D F cutting A^1 F^1 in R^1; then D^1 R^1 will be the length or slant hight of the cone at its longest points, and a line from R^1 projected back into the elevation will locate the base of the cone in that view, as shown at R.

From B as a center, with a radius equal to R^2 R^1, describe a circle in the plan, which will represent the base or plan of the cone. Divide an eighth of this circle into any number of equal parts, as shown by 1, 2, 3, 4 and 5, which spaces are to be used in measuring off the arc circumscribing the pattern. Draw any line, as D R in Fig. 506, upon which set off the several points in the line D R, as shown by the letters, and from D as center describe arcs indefinitely from each point, as shown. On the arc drawn from R step off spaces corresponding to one-eighth of the plan, as

shown by 1, 2, 3, 4 and 5. Draw the line D 5, as shown, cutting the arc from F, as indicated by *f*. By

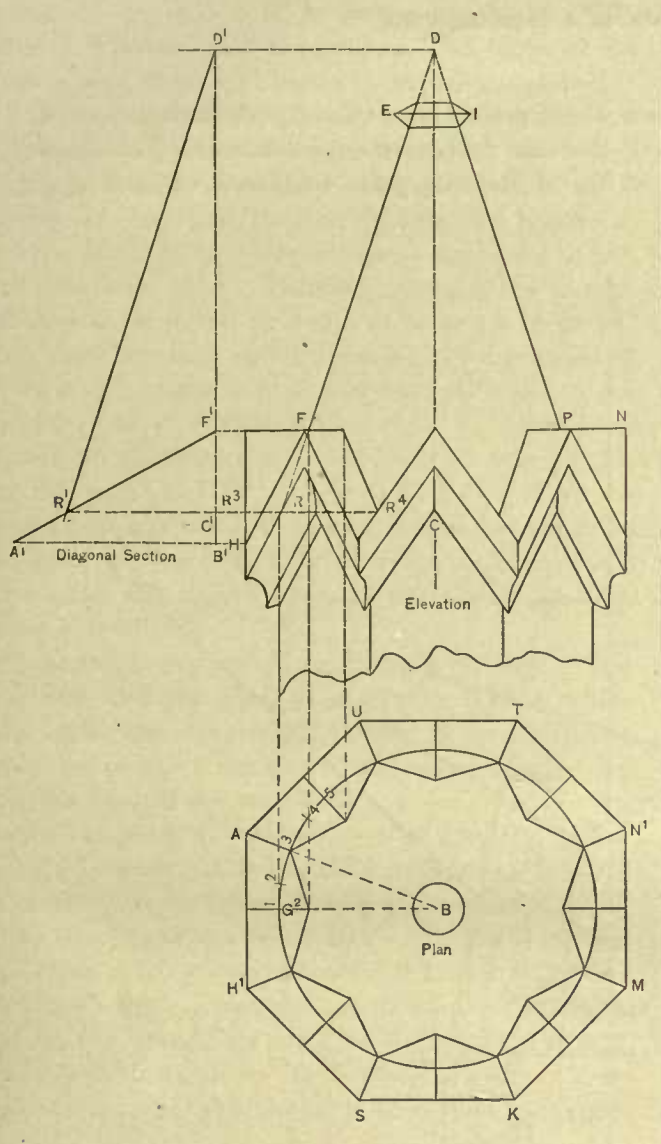


Fig. 505.—Elevation and Plan of Conical Spire Mitering upon Eight Gables.

inspection of the elevation it will be seen that the arc F represents the line of the top of the gables, and that the arc R represents the line of points in the base of the cone to fit down between the gables. Therefore from F to the middle point 3 draw F *g*, and from *f* draw *f g*. Then D *f g* F will be one-eighth of the required pattern. Set the dividers to 1 3 on the arc R and step off a sufficient number of additional spaces to complete the pattern, as shown by 3, 5, 3, 5, etc., to W. Draw W D. Also from the points 3 draw the lines *f g* and *g f*, thus completing the pattern.

In case the work is of large dimensions it will be advisable to miter the cone from F to *g*, *g* to *f*, etc., in the manner shown in the preceding problem, but in

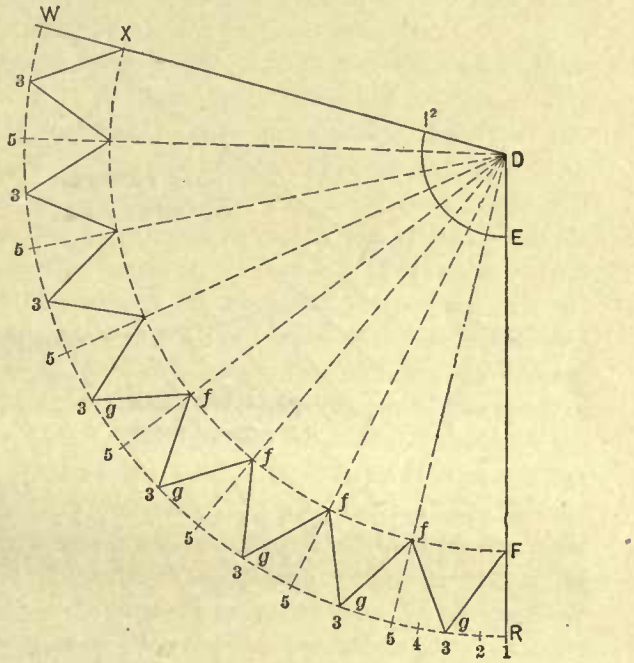


Fig. 506.—Pattern of Spire Shown in Fig. 505.

case the work is small it will be sufficiently accurate to make the lines *f g* straight, as shown.

PROBLEM 152.

Patterns for a Two-Piece Elbow in a Tapering Pipe.

In the solution of this problem two conditions may arise; in the first, the two pieces of the elbow have the same flare or taper, while in the second case one of the pieces may have more flare than the other. It has been shown in the chapter on geometrical problems that an oblique section through the opposite sides of a cone is a perfect ellipse. Keeping this in mind, it is evident that if the cone shown by A B C in Fig. 507 were made of some solid material and cut obliquely by the plane D E and the severed parts placed side by side, both would present to view two perfect ellipses of exactly the same proportions and dimensions; and, therefore, that if the two parts be placed together again, turning the upper piece half way around, as shown by D E A', the edges of the two pieces from D to E would exactly coincide.

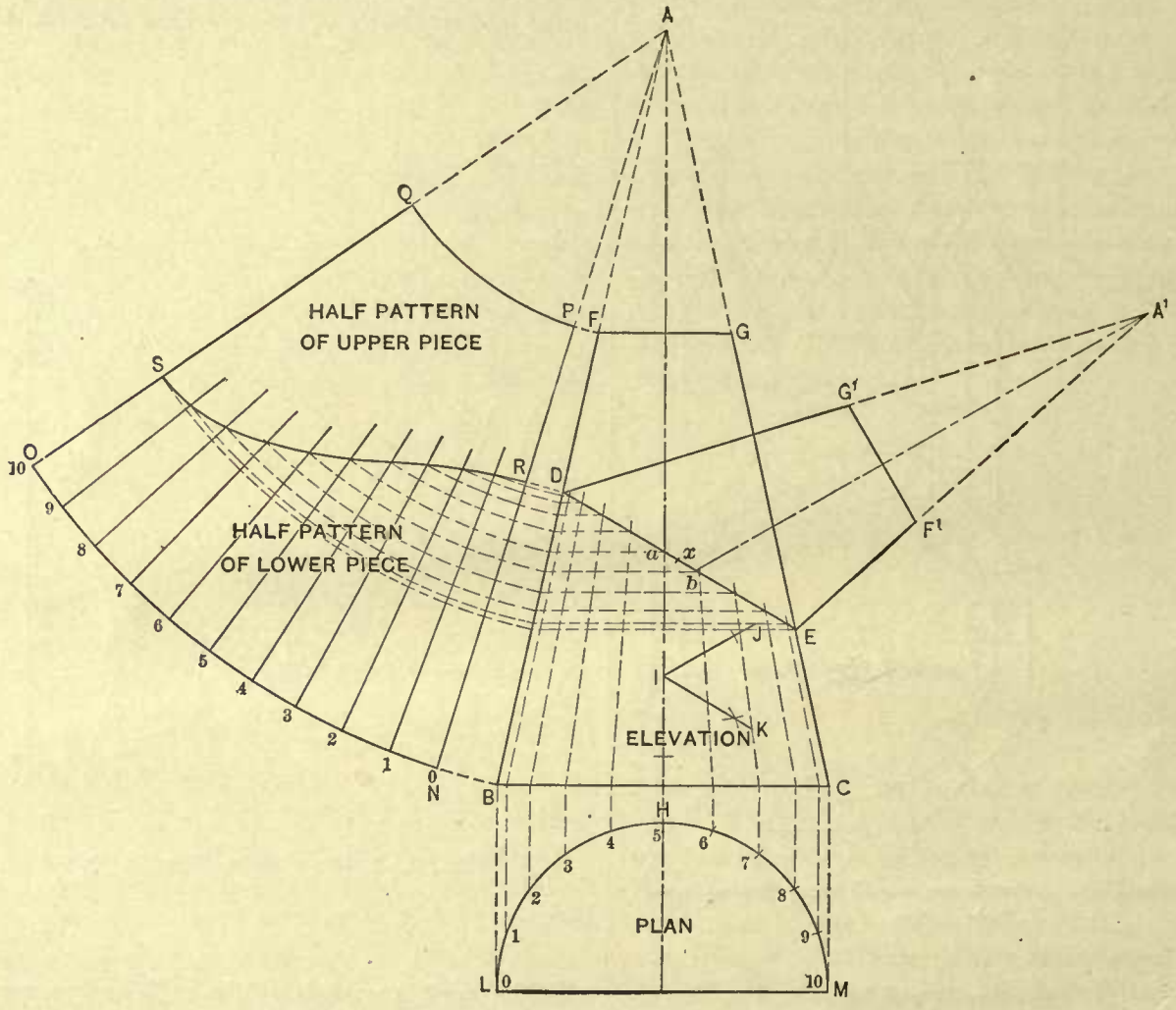


Fig. 507.—A Two-Piece Elbow in a Tapering Pipe.

Taking advantage of this fact, then, it only becomes necessary to ascertain the angle of the line D E, necessary to produce the required angle between the two pieces of an elbow, both of which have equal flare.

Therefore, at any convenient point upon the axis A H, as I, draw I J at the angle which the axis of the upper piece is required to make with that of the lower, then bisect the angle J I H, as shown by the line I K. Draw D E parallel to I K at the required hight of the lower piece, which will be the miter line sought.

Before completing the elevation of the elbow it will be necessary to notice a peculiarity of the oblique section of a cone—viz., that although the line A H bisects the cone and its base it does not bisect the oblique line D E, as by measurement the center of D E is found to be at *x*. Therefore, through the point *b*, which is as far to the right of *x* as point *a* is to the left of it, draw any line, as *b* A', parallel to I J and make *b* A' equal in length to *a* A, and draw A' D and A' E. Next draw G' F' at right angles to A' *b*, representing the upper end of the elbow. Make D F equal to E F', and E G equal to D G'. Then B F G C will be the elevation of a frustum of a cone, which, when cut in two upon the line D E, will, when the upper section is turned half-way around upon the lower part, form the elbow B D G' F' E C.

At any convenient distance below the base of cone B C draw half the plan, as shown by L H M, which divide into any convenient number of equal spaces. From the points of division erect lines vertically, cutting the base of the cone B C, and thence carry them toward the point A, cutting the miter line D E. Placing the T-square parallel to the base line B C bring it successively against the points in D E, cutting the side of the cone, as shown below D.

From A as center, with radii A B and A F, draw arcs, as shown. Upon the arc drawn from B, beginning at any convenient point, as N, step off a stretchout of L H M, as shown by the small figures. From each of the points thus obtained draw measuring lines toward the point A, and from the last point O one cutting the arc drawn from F at Q. Placing one point of the compasses at the point A, bring the pencil point in turn to each of the points in the side of the cone below D and cut measuring lines of corresponding number. Then a line traced through the points of intersection, as shown from S to R, will be the miter cut between the two parts of the pattern of the frustum O N P Q necessary to form the patterns of the required elbow.

As but half the plan of the cone was used in obtaining a stretchout, the drawing shows but halves of the patterns. In duplicating the halves to form the complete patterns the upper piece can be doubled upon the line Q S and the lower part upon the line R N, thus bringing the joints on the short sides.

If, according to the second condition stated at the beginning of this problem, the upper section of this elbow is required to have more or less flare than the lower section, thereby placing the apex A' nearer to or farther away from the line D E, a different course will have to be pursued in obtaining the pattern. If, for instance, the hight of the cone A H be reduced, the base B C remaining the same, the proportions—that is, the comparative length and width—of the ellipse derived from the cut D E would be different from those derived from the same cut were the proportions of the cone to remain unchanged. Therefore, since the shape of the lower piece at the line D E is a fixed factor, if the circle at G' F' be shifted up or down the axis, or, remaining where it is, its diameter be changed, the piece D G' F' E becomes an irregular tapering article, in which case its pattern can most easily be obtained by triangulation. Patterns for pieces embodying those conditions can be found in Section 3 of this chapter, to which the reader is referred.

PROBLEM 153.

Patterns for a Three-Piece Elbow in a Tapering Pipe.

In Fig. 508 is shown a three-piece elbow occurring in taper pipe, in which the flare is uniform throughout the three sections. In solving this problem the simplest method will be to construct the elevation of the elbow and an elevation of an entire cone, from which several sections may be cut to form the required elbow, at one and the same time. Therefore in the elevation of the cone E F G let L' M' be drawn at a distance from E F equal to the total length of the three pieces measured upon their center lines, and also let its length be equal to the diameter of the elbow at its smaller end; then through E and L' and

through F and M' draw the sides of the cone, intersecting in G.

At any convenient point, as B, draw the line B A at the angle which the axis of the middle piece is required to make with that of the lower (in this case 45 degrees), and bisect the angle A B C, as shown, by the line B D. Parallel with B D draw P R at any required hight, upon which locate the point I making P I equal to R J. (The reason for this is explained in the previous problem.) From the point I draw the axis of the second section of the elbow parallel with A B, making it (I H) equal to J G, and draw P H and R H.

From any convenient point upon this axis, as U, draw U S at the required angle which the axis of the upper piece is required to make with that of the middle piece (in this case also 45 degrees, or horizontal), and bisect the angle S U I, as shown, by U T. Then the miter line N O can be drawn parallel with U T at any required distance from I, upon which locate the point *i*, making N *i* equal to O *j*. From *i* draw the axis of the upper piece of the elbow parallel with U S, making *i* K equal to *j* H. Next locate the line N O upon the original cone, making N' P equal to O R and O' R equal to P N. Now make N L equal to N' L and M O equal to M' O' and draw M L.

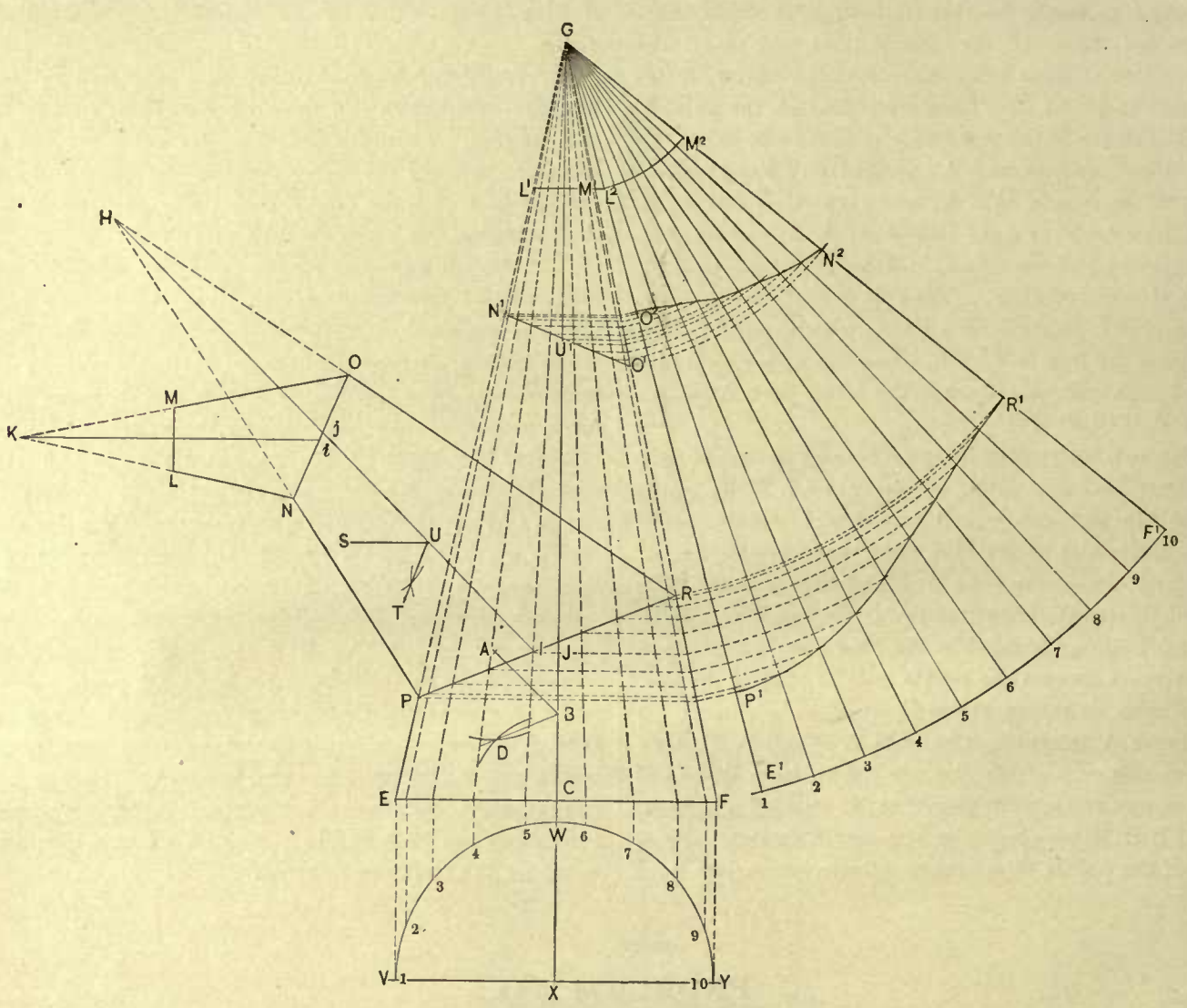


Fig. 508.—A Three-Piece Elbow in a Tapering Pipe.

It may be remarked here that on account of the shifting of the positions of the axes of the several

pieces upon the miter lines by turning them, as shown by I J and *i j*, it will be impossible to ascertain with extreme accuracy the lengths of the various pieces upon their axes until the elevation E P N L M O R F is drawn, and therefore to obtain the position which the line M L will occupy.

This method of solving the problem is given upon the supposition that its simplicity will compensate for this slight inaccuracy, as usually differences of length can be made up in the parts with which the elbow may be connected. If the lines M L and E F are to be assumed at the outset as fixed factors between which a tapering elbow is to be constructed, it will be somewhat difficult to ascertain the exact dimensions of a cone, E F G, which can be cut and its parts turned so as to constitute the required elbow. Hence, while two of the pieces (say the two lower ones) can easily be cut from an entire cone assumed at the outset, the third piece will have to be drawn arbitrarily to fit between the last miter line N O and the small end M L, and will very likely be of different flare from that of the other two pieces. This will necessitate the last section being cut by the method of triangulation, problems in which are demonstrated in Section 3 of this chapter, to which the reader is referred.

Having, as explained above, obtained the lines of cut through the cone, the patterns may be described as follows: Draw the plan V W Y, its center X falling upon the axis of the cone produced, which divide in the usual manner into any convenient number of equal parts. Through the points thus obtained erect perpendiculars to the base E F, and thence carry lines toward the apex G, cutting the miter lines P R and N^1 O^1. With the T-square at right angles to the axis G C, and brought successively against the points in N^1 O^1 and P R, cut the side G F of the cone, as shown by the points above O^1 and below R. From G as center, with radius G F, describe the arc E^1 F^1, upon which lay off the stretchout of the plan V W Y, as shown by the small figures 1, 2, 3, etc., and from these points draw measuring lines to the center G. From G as center describe arcs corresponding to the distance from G to the several points established in G F, which produce until they intersect lines of corresponding numbers drawn from the center G to the arc E^1 F^1. Through these points of intersection trace lines, as shown by O^2 N^2 and P^1 R^1. From G as center, with radius G M^1, describe the arc L^2 M^1. Then L^2 M^2 N^2 O^2 is the half pattern of the upper section, O^2 N^2 R^1 P^1 that of the middle section, and P^1 R^1 F^1 E^1 that of the lower section.

PROBLEM 154.

The Patterns for a Regular Tapering Elbow in Five Pieces.

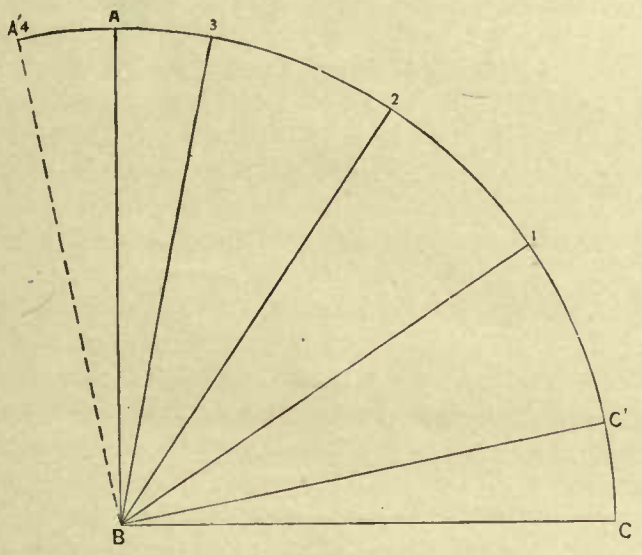


Fig. 509.—Diagram of Angles for a Five-Piece Elbow.

In this problem, as in the two immediately preceding, the various pieces necessary to form the elbow may be cut from one cone, whose dimensions must be determined from the dimensions of required elbow. The first essential will be to determine the angle of the cutting lines, which may be done the same as if the elbow were of the same diameter throughout.

Such an elbow of five pieces would consist of three whole pieces and two halves; therefore, if it is to be a right angle elbow, divide any right angle, as A′ B C′ in Fig. 509, into four equal parts, as shown by the points 1, 2, 3. Bisect the part A′ B 3 by the line A B and transfer the portion A′ B A to the opposite side of the figure, as shown by C′ B C.

This gives the right angle A B C divided into the same number of pieces and half-pieces as would be employed in constructing an ordinary five-piece elbow,

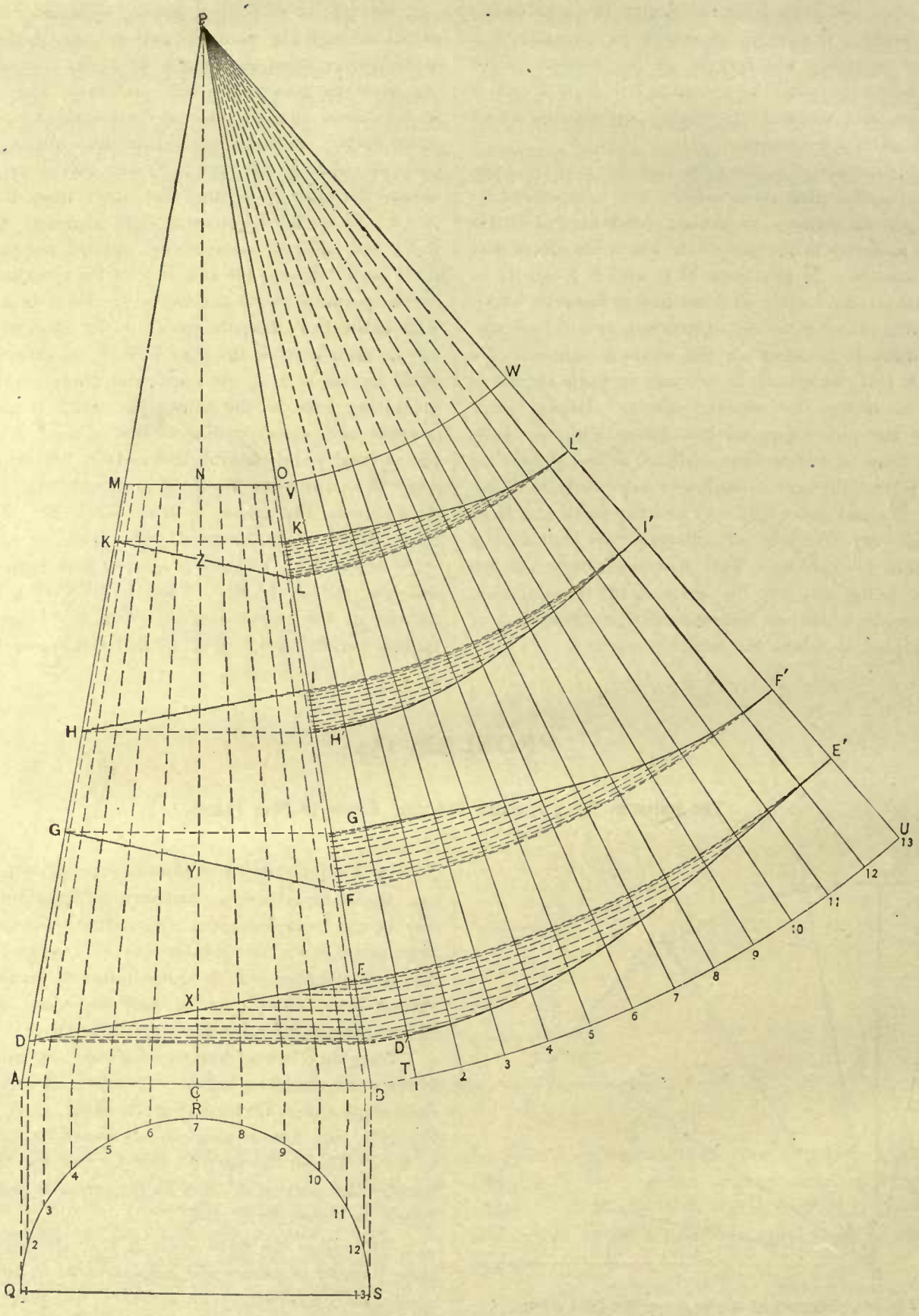


Fig. 510.—A Five-Piece Elbow in a Tapering Pipe.

The division lines in this diagram are of the correct angle for the miter lines in the elbow pattern, and therefore can be used upon the diagram of the cone, out of which are to be obtained the pieces to compose the required elbow.

It is assumed that the amount of rise and projection are not specified, therefore after having got the line of the angle or miter it becomes a matter of judgment upon the part of the pattern cutter what length

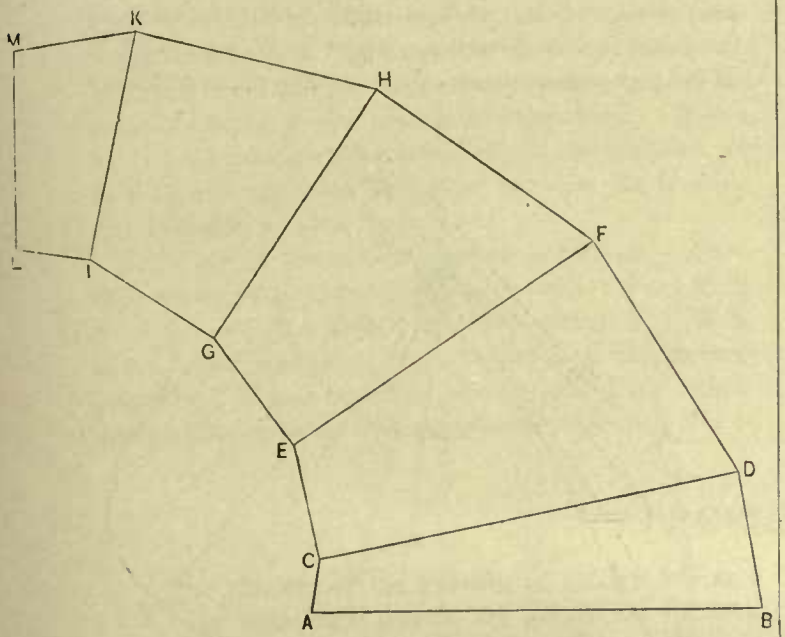


Fig. 511.—Elevation of Five-Piece Tapering Elbow.

shall be given to each of the pieces composing the elbow.

In Fig. 510, let A B represent the diameter of the large end of the elbow. From the middle point in the line A B, as C, erect a perpendicular line, as indicated by C N, producing it indefinitely. On the line C N, proceeding upon judgment, as already mentioned, set off C X to represent the length of the first section of the elbow measured upon its center line. With X thus determined, draw through it the line D E, giving it the same angle with A B as exists between B C' of Fig. 509 and the horizontal B C. This, in all probability, can most readily be done by extending B A indefinitely beyond A and letting E D intersect with B A extended, producing at their intersection an angle equivalent to C B C' of Fig. 509. From the point X set off the distance X Y, also established by judgment, thus determining the position across the cone of the miter line of the next section. Through Y draw G F at the same angle as D E, already drawn, but inclined in the opposite direction. In like manner locate the two other miter lines shown in the diagram, finally obtaining the point Z. From Z set off the width toward N of the last section of the pattern, and through the point N thus obtained draw the line M O at right angles to C N, making it in length equal to the diameter of the small end of the elbow and placing its central point at N. Through the points A M and B O of the figure thus constructed draw lines, which produce indefinitely until they intersect the axis in the point P. Then P will be the apex of the required cone.

Construct a plan of the base of the cone or large end of the elbow below and in line with the diagram, as shown in the drawing, which divide into any convenient number of spaces, as indicated by the small figures, and from the points thus obtained carry lines vertically, cutting the base of the cone A B. From A B continue them toward the apex of the cone, cutting the several miter lines drawn. With the apex P of the cone for center, and with P B as radius, describe the arc T U, upon which set off a stretchout of one-half the plan, all as indicated by the small figures. From the points thus established in T U carry lines to the center P. With the T-square placed at right angles to the axis N C of the cone, and brought against the points of intersection in the several miter lines made by the lines drawn from points in the base of the cone to the apex, cut the side O B of the cone, as shown. Then from P as center, with radii corresponding to the distance from P to the several points on O B, as mentioned, strike arcs cutting the lines of corresponding numbers in the pattern diagram, as shown. Then lines traced through the points thus obtained, as indicated by D' E', F' G', etc., will cut the pattern O W U T of the frustum in such a manner that the sections will constitute the half patterns of the pieces necessary to form the required elbow. In Fig. 511 is shown an elevation of the elbow resulting from the preceding operation.

PROBLEM 155.

The Frustum of a Cone Intersecting a Cylinder of Greater Diameter than Itself at Other than Right Angles.

In Fig. 512, E G H F represents an elevation of the cylinder, and M N L K an elevation of the frustum of a cone intersecting it. F' Z Q represents the profile or plan of the cylinder, to which it will be necessary to add a correctly drawn plan of the frustum before the miter line in elevation can be obtained. At any convenient point on the axial line T O of the cone construct the profile V Y X W, which represents a section through the cone on the line M N. Divide the section V Y X W into any convenient number of equal spaces in the usual manner, as shown by the small figures 1, 2, 3, 4, etc. From each of the points thus established drop lines parallel with the axis of the cone cutting the line M N. From the interseetions in M N thus obtained drop points parallel with the side G H of the cylinder and continue them indefinitely, cutting the line F' O', which is drawn through the center of the plan of the cylinder at right angles to the elevation, all as shown in the engraving. Make Y' W' equal to Y W of the first section constructed. In like manner measure

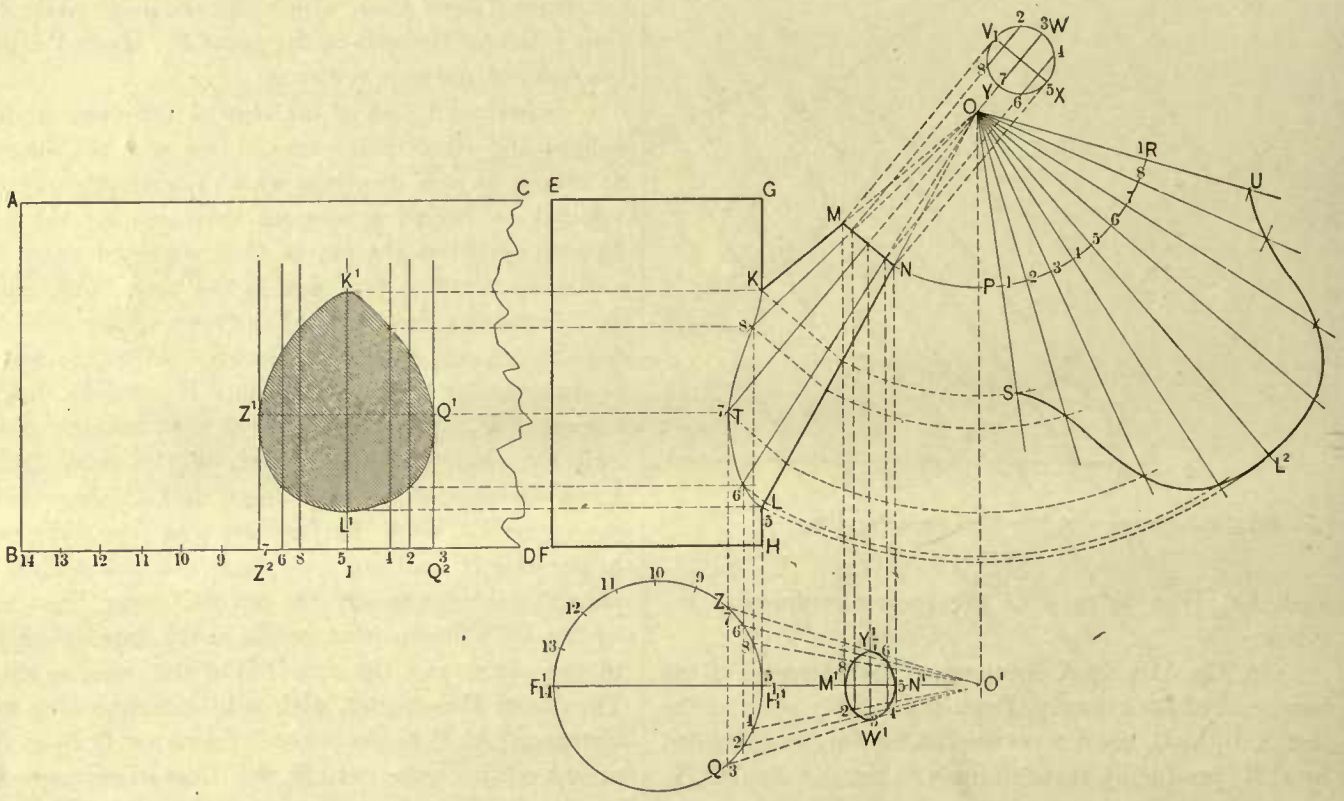


Fig. 512.—The Frustum of a Cone Intersecting a Cylinder of Greater Diameter than Itself at Other than Right Angles.

distances from the center line V X of the first section to the points 2, 3, 4, etc., and set off corresponding spaces in the plan view, measuring from M' N', upon lines of corresponding numbers dropped from the intersections in M N, already described. Then a line traced through these points will represent a view of the upper end of the frustum as it would appear when looked at from a point directly above it. Produce the

sides of the frustum K M and L N until they meet in the point O. From O drop a line parallel to the side G H of the cylinder, cutting the line F' O' in the point O', thus establishing the position of the apex of the cone in the plan. From the point O' thus established draw lines through the several points in the section M' Y' N' W', which produce until they intersect the plan of the cylinder in points between Z' and Q, as shown in the engraving. From O, the apex of the cone in the elevation, draw lines through the several points in M N already determined, which produce until they cross G H, the side of the cylinder, and continue them inward indefinitely. Intersect these lines by lines drawn vertically from the points of corresponding number between Z and Q of the plan just determined. Then a line traced through these intersections, as indicated by K T L, will represent the miter between the frustum and cylinder, as seen in elevation.

To lay off the pattern proceed as follows: From O as center, with O N as radius, describe the arc P R, on which set off a stretchout of the section Y V W X in the usual manner. From O, through the several points in P R thus obtained, draw radial lines indefinitely. From the several points in the miter line K T L draw lines at right angles to the axis O T of the cone, producing them until they cut the side N L. From O as center, with radii corresponding to the distance from O to the several points in N L just obtained, describe arcs, which produce until they intersect radial lines of corresponding number drawn through the stretchout P R. Then a line traced through these points of intersection, as indicated by S L² U, will be the lower line of the pattern sought, and P S L² U R will be the complete pattern.

The pattern for the cylinder and the opening in the same to fit the intersection of the cone is really a problem in parallel forms, with which problems (Section 1) it should properly be classed. F' Z Q is the profile of the cylinder, and L T K is the miter line. The stretchout B D is drawn at right angles to E F, the direction of the mold or cylinder. The points between Z² and Q² of the stretchout are duplicates of those between Z and Q of the plan. Place the T-square at right angles to the cylinder, and, bringing it successively against the points in the miter line K T L, cut lines of corresponding numbers. A line traced through the points of intersection thus formed, as shown by Z' K' Q' L', will be the shape of the required opening in the cylinder.

PROBLEM 156.

The Patterns of the Frustum of a Cone Joining a Cylinder of Greater Diameter than Itself at Other than Right Angles, the Axis of the Frustum Passing to One Side of That of the Cylinder.

Let E F H G in Fig. 513 be the elevation of a cylinder, which is to be intersected by a cone or frustum, D A J C, at the angle F D A in elevation, and which is to be set to one side of the center, all as shown by S P L M R of the plan. Opposite the end of the frustum, in both elevation and plan, draw a section of it, as shown by T U V W in the elevation and T' U' V' W' in the plan. Divide both of these sections into the same number of equal parts, commencing at corresponding points in each, and number them as shown by the small figures in the diagram. From the points in T U V W carry lines parallel to the axis of the cone, cutting the line A J, and thence drop them vertically across the plan. From the points in the section T' U' V' W' draw lines parallel to the axis of the cone, as seen in plan, intersecting the lines of corresponding number dropped from A J just described. Through these points of intersection trace a line, as shown by L M. Then L M will show the end of the frustum A J as it appears in plan. From X, the apex of the cone in elevation, drop a line vertically, cutting the axis of the cone in plan as shown at X'. From X draw lines through the points in A J and extend them through the side of the cylinder indefinitely. From X' through the points in L M draw lines cutting the plan of the cylinder, as shown from P to R, and from these points carry lines vertically, intersecting those of corresponding number in the elevation drawn from the apex X. Then a line traced through these points, as shown by D K C N, will be the miter line in elevation.

For the pattern of the frustum, from X as center, with radius X A, describe the arc A' J', upon which lay off a stretchout of the section T U V W, through the points in which, from X, draw radial lines indefinitely. From the points in D K C N carry lines at right angles to the axis of the cone, cutting the side A D extended, as shown from D to B. From X as

center, with radii corresponding to the distance from X to the various points in the line D B, describe arcs cutting radial lines of corresponding number in the pattern. Through the points of intersection in the pattern thus obtained trace a line, as shown by C' K' N' D'. Then D' N' K' C' A' J' will be the pattern of the frustum D A J C, mitering with the cylinder at the angle described.

The method of obtaining the pattern of the cylinder is analogous to that described in the preceding problem, and is clearly shown at the left in the drawing.

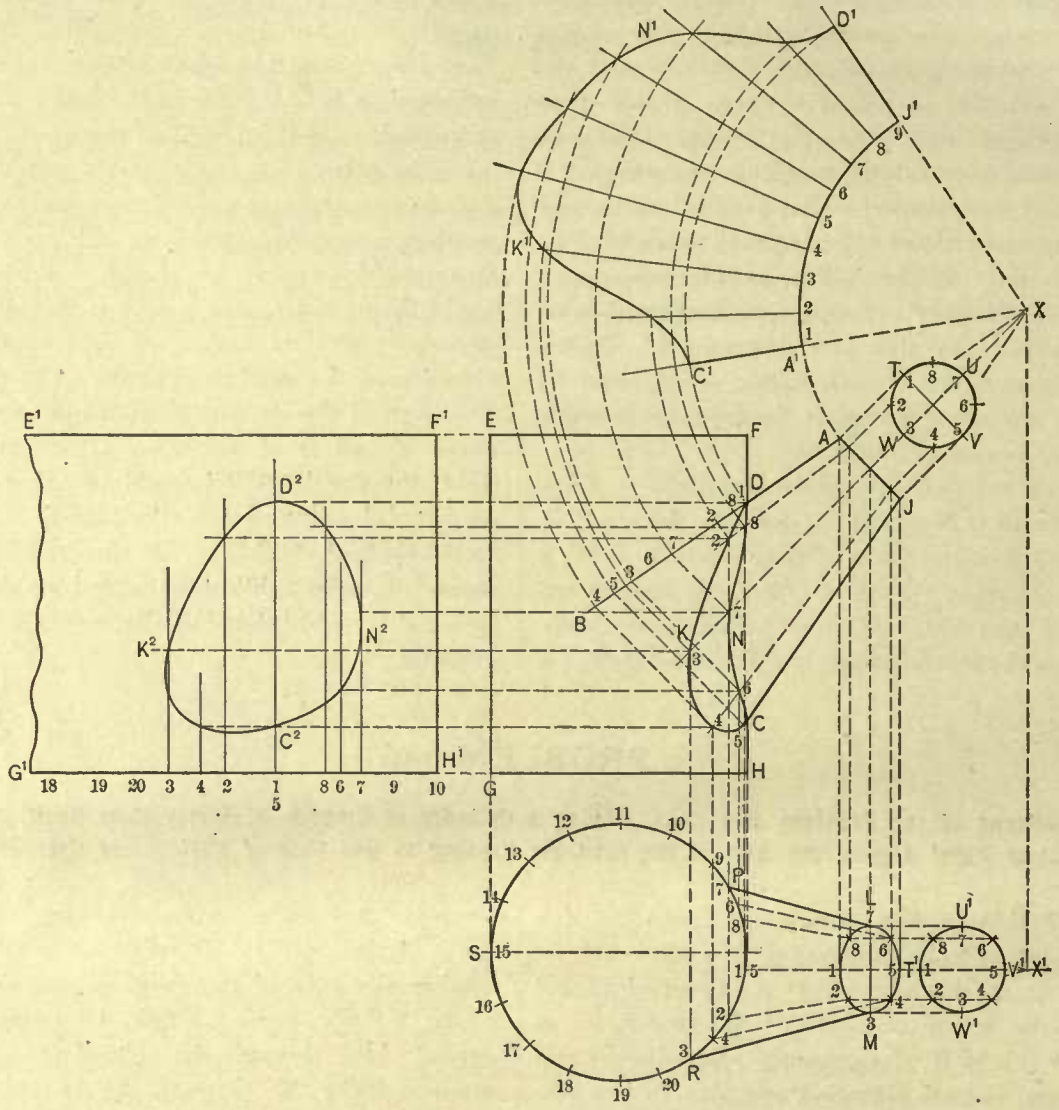


Fig. 513.—The Patterns of the Frustum of a Cone Joining a Cylinder of Greater Diameter than Itself at Other than Right Angles, the Axis of the Frustum Passing to One Side of that of the Cylinder.

PROBLEM 157.

The Patterns of a Cone Intersected by a Cylinder of Less Diameter than Itself, Their Axes Crossing at Right Angles.

In Fig. 514, let B G E D F A C be the elevation of the required article. Draw the plan in line with the elevation, making like points correspond in the two views, as shown by M O S T U P N. Let D M E be a half section of the cylinder in the elevation and D' M' E' a corresponding section in the plan.

Divide these sections into any convenient number of equal parts, commencing at the same point in each, as shown by the small figures, and draw the center line of the cylinder in plan D' R. From each of the points in the section shown in elevation carry lines parallel to D

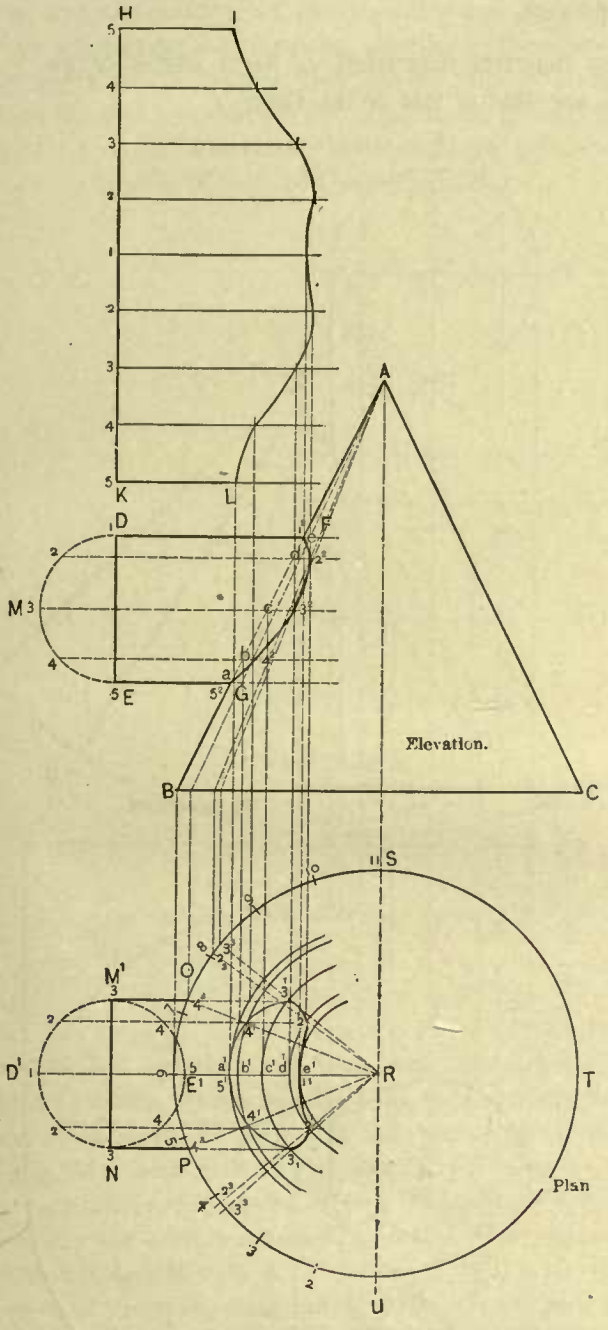


Fig. 514.—A Cone Intersected by a Cylinder of Less Diameter than Itself at Right Angles to Its Axis.

F cutting the side of the cone, and extend them some distance into the figure for further use. From the several points of intersection with the side of the cone, as shown by *a*, *b*, *c*, *d* and *e*, drop lines parallel to the axis of the cone cutting the line D' R of the plan, giving the points a', b', c', d' and e', and through each of these points, from R as center, describe an arc, as indicated in the engraving. From the points in the profile D' M' E' of the plan draw lines parallel to the sides of the cylinder, producing them until they meet the arcs drawn through corresponding points, giving the points indicated by 1', 2', 3', 4' and 5'. From these points carry lines vertically to the elevation, producing them until they meet the lines drawn from points of corresponding numbers in the profile of the cylinder in the elevation, giving the points 1^2, 2^2, 3^2, 4^2 and 5^2. A line traced through these points, as shown from G to F, will be the miter line in elevation formed by the junction of the cylinder and the cone.

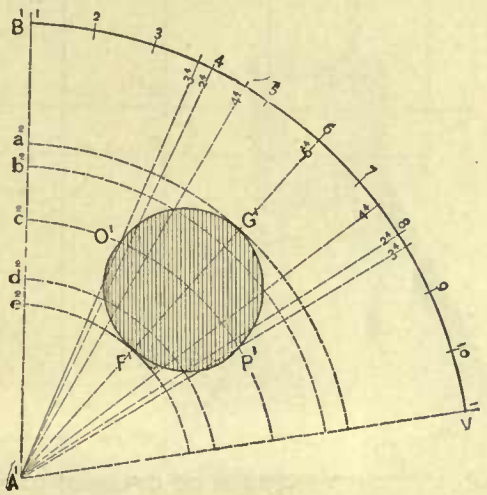


Fig. 515.—Half Pattern of the Cone Shown in Fig. 514.

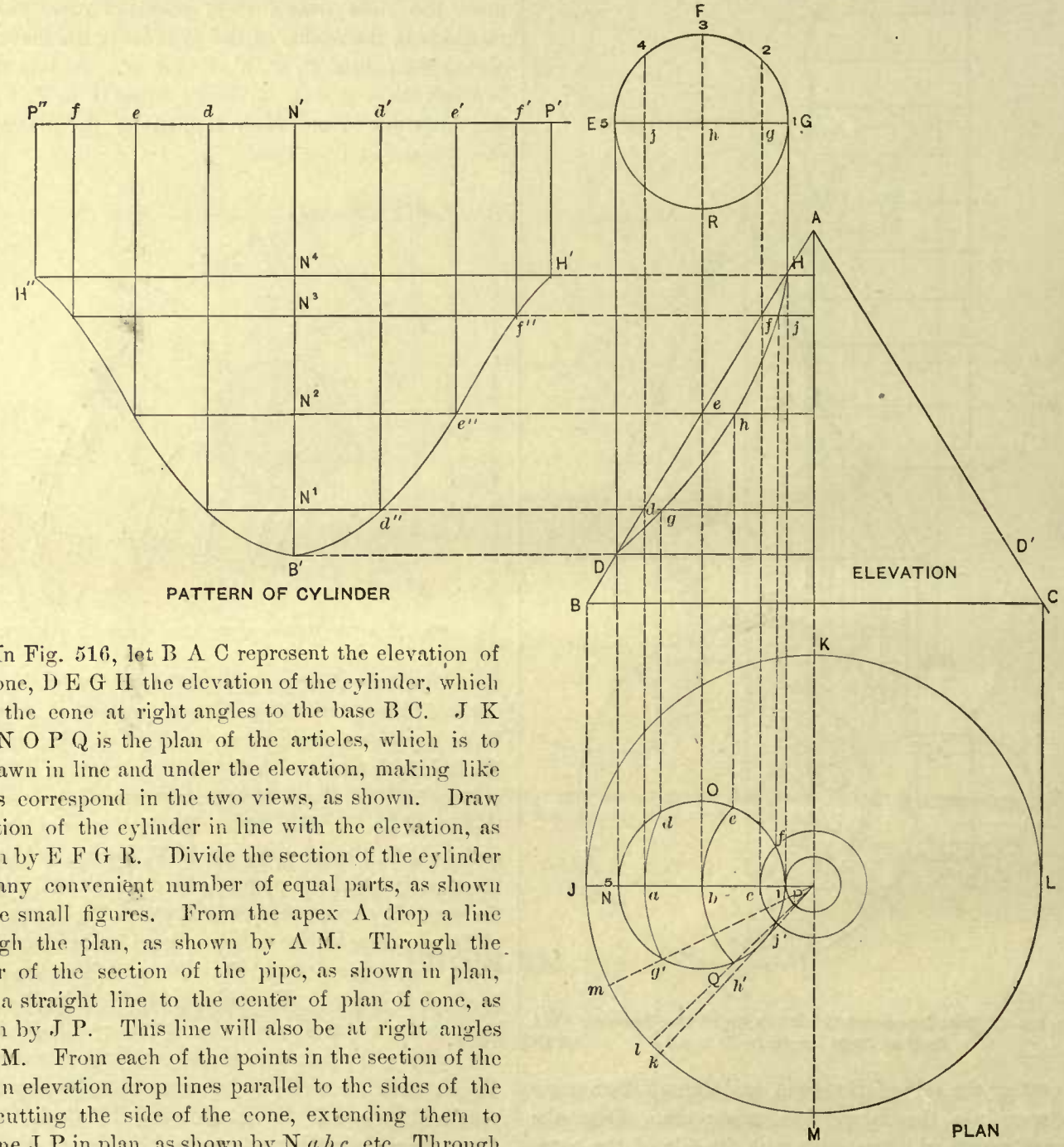
To obtain the envelope of the cone with the opening to fit the intersecting cylinder proceed as follows: From any convenient point, as A', Fig. 515, draw A' B', in length equal to A B of the elevation. Set off points e^2, d^2, c^2, b^2 and a^2 in it, corresponding to *e*, *d*, *c*, *b* and *a* of A B, Fig. 514. From A' as center, with radius A' B', describe the arc B' V, upon which lay off the stretchout of the plan of the cone, as indicated by the small figures outside of the pattern. (But one-half of the envelope of the cone is shown in the engraving.) From the same center A' describe arcs from the points e^2, d^2, c^2, b^2 and a^2. From the center R of the plan draw lines to the circumference through the points 2', 3', 4', etc., giving the points in the circumference marked 2^2, 3^2, 4^2, etc. Set off by measurement corresponding points in the arc B' V, as shown by 3^4, 2^4, 4^4, 5^4, etc. From these points draw lines to the center A', intersecting the arcs of corresponding number drawn from

a^2, b^2, e^2, etc. A line traced through these points of intersection, as shown by F^1 O^1 G^1 P^1, will be the shape of the opening to be cut in the side of the cone to fit the mitered end of the cylinder.

The pattern for the cylindrical part is shown above the elevation, and is obtained in accordance with the principles demonstrated in the first section of this chapter, which need not be here repeated.

PROBLEM 158.

The Patterns of a Cone Intersected by a Cylinder of Less Diameter than Itself at Right Angles to its Base, the Axis of the Cylinder Being to one Side of that of the Cone.



In Fig. 516, let B A C represent the elevation of the cone, D E G H the elevation of the cylinder, which joins the cone at right angles to the base B C. J K L M N O P Q is the plan of the articles, which is to be drawn in line and under the elevation, making like points correspond in the two views, as shown. Draw a section of the cylinder in line with the elevation, as shown by E F G R. Divide the section of the cylinder into any convenient number of equal parts, as shown by the small figures. From the apex A drop a line through the plan, as shown by A M. Through the center of the section of the pipe, as shown in plan, draw a straight line to the center of plan of cone, as shown by J P. This line will also be at right angles to K M. From each of the points in the section of the pipe in elevation drop lines parallel to the sides of the pipe cutting the side of the cone, extending them to the line J P in plan, as shown by N a b c, etc. Through each of these points, from P as center, describe circles,

Fig. 516.—Plan and Elevation of Cone Intersected by a Cylinder at Right Angles to its Base.

as shown, cutting the sides of the plan of cylinder. From each of the points of intersection with the side of the cone (A B) draw lines parallel with the base, and extend them inward. If it is desired to show the miter line in elevation formed by the junction of pipe and cone, from the points *d e f* in the plan of cylinder carry lines vertically to the elevation, producing them until they meet the horizontal lines having similar letters drawn through the side of the cone A B, giving the points *g h j*. A line traced through these points, as shown by D *g h j* H, will be the miter line.

H *f e d* D of elevation, as shown by H *c b a* D. From the center A of pattern describe arcs cutting the points H *c b a* D.

It is only necessary now to make each of these arcs equal in length to the one to which it corresponds in the plan by any method most convenient. Thus make *a d* and *a d'* equal to *a d* of the plan, *b e* and *b e'* equal to *b e* of the plan and *c f* and *c f'* equal to *c f* of the plan. A line traced through these points, as shown by H Q D O, will be the shape of the opening. Another method of making the measurements of the arcs is shown by

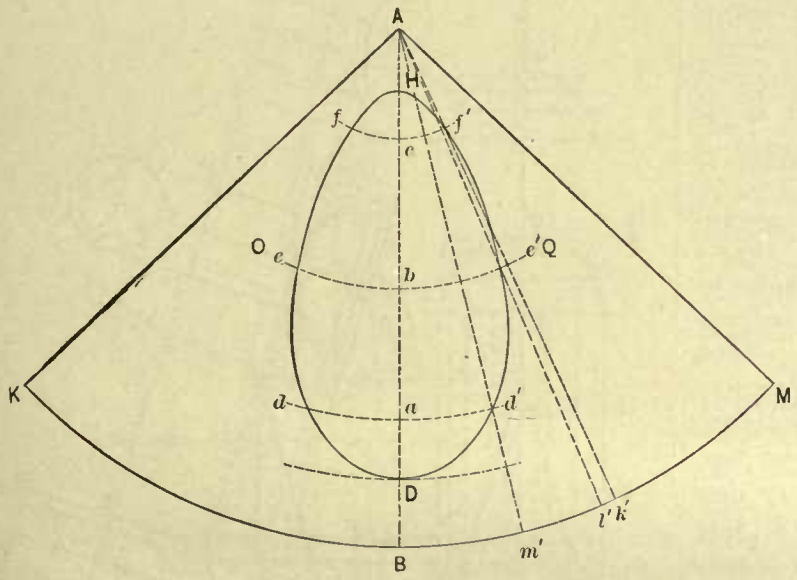


Fig. 517.—Half Pattern of Cone Shown in Fig. 516.

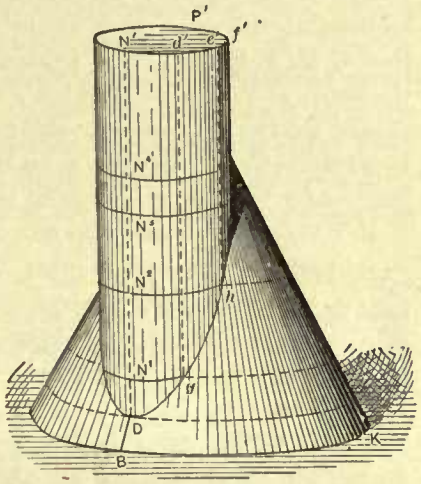


Fig. 518.—Perspective View of Cone and Cylinder Shown in Fig. 516.

The half pattern of the cone, with the opening to fit the cylinder, is shown in Fig. 517, to describe which proceed as follows: From any convenient point, as A in Fig. 517, with A B of Fig. 516 as radius, strike an arc indefinitely, as shown. From B of pattern set off each way the stretchout of J M and J K of plan and connect K and M with A. Then K A M B is the half pattern of the cone, or as much as shown on plan by K J M. To obtain the shape of opening to be cut in cone to correspond with the shape of pipe, on A B, the center line of pattern, set off points corresponding to the radial dotted lines of the plan and pattern in the manner explained in the problem immediately preceding.

The pattern for the cylinder is obtained in the manner usual with all parallel forms, its only peculiarity in this case being that its stretchout is taken from the irregular spaces upon the profile N O P Q of the plan, which are transferred to the line P′ P″, as shown.

A pictorial representation of the finished article is shown in Fig. 518, upon which some of the lines of measurement shown in Fig. 516 have been traced.

PROBLEM 159.

Patterns of a Cylinder Joining a Cone of Greater Diameter than Itself at Right Angles to the Side of the Cone.

Let B A K in Fig. 519 be the elevation of a right cone, perpendicular to the side of which a cylinder, L S T M, is to be joined. The first operation will be to describe the miter line as it would appear in elevation. Draw the section U V of the cylinder, which divide into any convenient number of equal parts, as indicated by the small figures, and from these points drop lines parallel to L S, cutting the side A K of the cone in the points H, F and D, producing them until they cut the axis A X in the points G, E and C. In order to ascertain at what point each of these lines will cut the envelope of the cone it will be necessary to construct sections of the cone as it would appear if cut on the lines G H, E F and C D. Draw a second elevation of the cone, as shown by B¹ A¹ K¹, representing the cone turned quarter way round; the first may be regarded as a side elevation and this as an end elevation. Draw a plan under the side elevation of the cone, as shown by N R P O, which divide into any convenient number of equal parts, and in like manner draw a corresponding plan or half plan under the end elevation, as shown by R¹ P¹ O¹. Divide this second plan into the same spaces, numbering them to correspond with the other plan. From the points 1 to 5 in plan N R P O carry lines vertically to the base B K and thence toward the apex A, cutting the lines C D, E F and G H. In like manner, from the same points (1 to 5 inclusive) in the plan R¹ P¹ O¹ carry vertical lines to the base B¹ K¹ and thence toward the apex A¹. Place the T-square at right angles to the axes of the two cones, and, bringing it against the points of intersection of the lines from X to K with C D, cut corresponding lines in the second elevation, and through the points of intersection thus established trace a line, as shown by C³ C⁴. Produce the axis X¹ A¹ to any convenient distance, upon which set off C¹ D¹, in length equal to C D, in which set off the points corresponding to the points in C D, and through these points draw lines at right angles to C¹ D¹. Place the T-square parallel to the axis X¹ A¹, and, bringing it against the several points in C³ C⁴, cut the lines of corresponding number drawn through C¹ D¹, as shown, and through the intersections thus established trace a line, as shown. Then C¹ D¹ is a section of the cone as it would appear if cut on the line C D.

In like manner carry lines from the points upon E F across to the end elevation, intersecting them with lines of corresponding number, as shown from E³ to E⁴, and thence carry them parallel to the axis, cutting lines drawn through E¹ F¹, which with its points has been

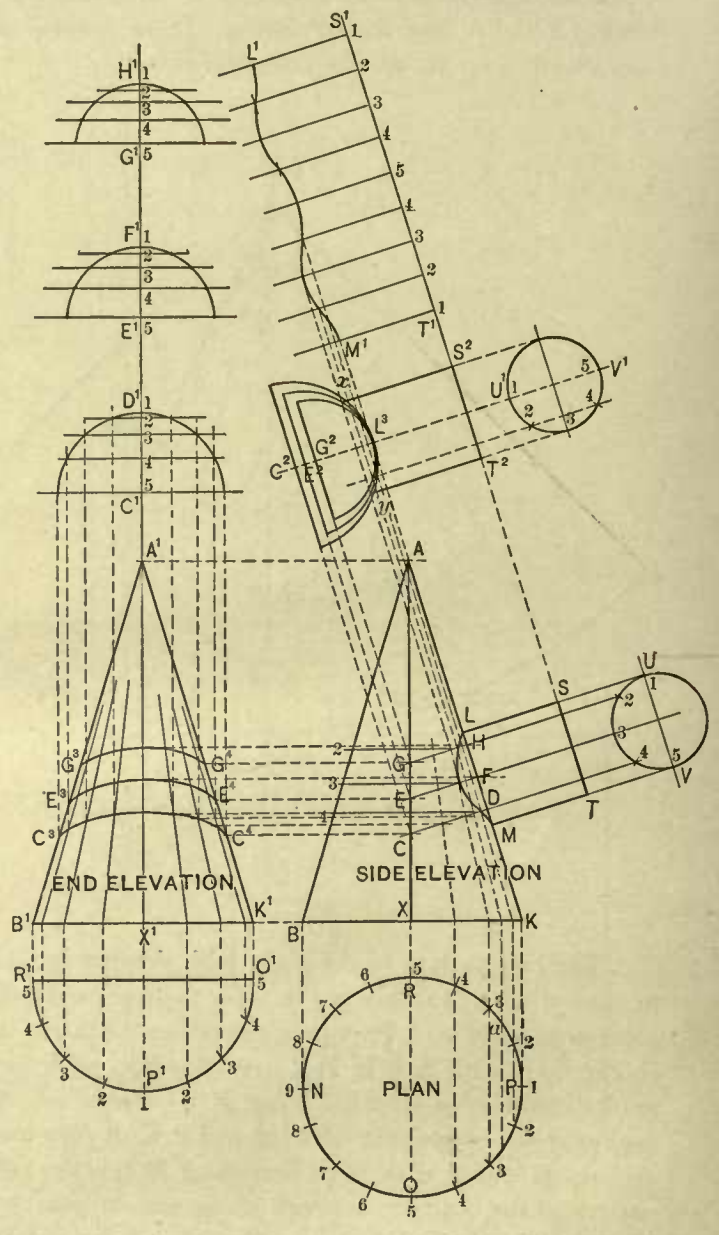


Fig. 519.—A Cylinder Joining a Cone of Greater Diameter than Itself at Right Angles to the Side of the Cone.

made equal to E F. The resulting profile E¹ F¹ is a section of the cone as it would appear if cut on the line E F. Also use the points in G H in like manner, es-

tablishing the profile G' H', which represents a section of the cone as it would appear if cut on the line G H. (Some of the lines indicating the operation in connection with sections E' F' and G' H' are omitted in the engraving to avoid confusion.)

Having thus obtained sections of the cone corresponding to the several lines C D, E F, G H, it will next be necessary to project a plan of the cone, with its intersecting cylinder, at right angles to L S, or as viewed in the direction of A K, which plan shall include all of these sections. To do this extend the line

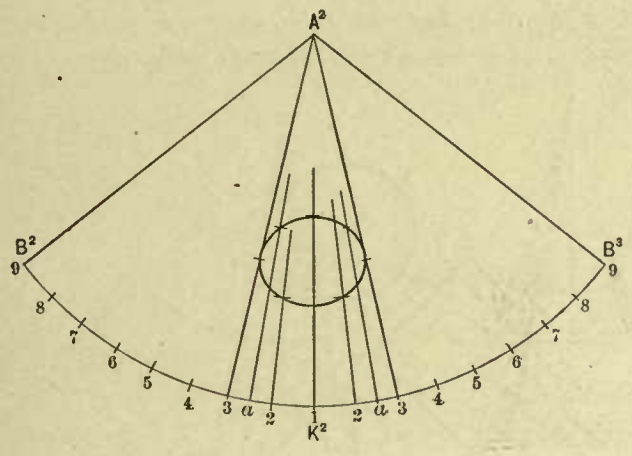


Fig. 520.—Envelope of Cone Shown in Fig. 519.

A K to a convenient distance above the elevation, and project lines from all other important points parallel to the same, as shown. At right angles to A K draw any line, as C² V', as a center line of the new plan. As the points D', F' and H' of the oblique sections of the cone are all in the line A K, transfer these sections to the new plan, so placing them that their center lines shall coincide with the center line of the new plan, and the points D', F' and H' shall be at the intersection of A K with the center line of the plan, all as shown. Opposite the end of the cylinder draw a section, as indicated by U' V', which divide into the same number of equal parts as used in the divisions of U V, commencing the division at corresponding points in each. As both halves of the cylinder and of the cone, when divided by a vertical plane passing through the axis of each, are the same, only one-half of the section of the cylinder has been numbered. From the points in U' V' drop lines parallel to C² V', each line cutting its corresponding section, as shown from *x* to *y*, and then carry them parallel to A K back to the elevation, cutting lines of corresponding number in that view. That is, from the intersection of the line drawn from point 4 in U' V' with the profile C² L² cut the line C D, which in the elevation corresponds to the point 4 in the profile U V, and from the intersection of a line drawn from 3 with E² L² cut the line E F, and so on, all as indicated by the dotted lines. Then a line traced through these points of intersection, as shown by L M, will be the miter line in elevation, from which the patterns may readily be obtained.

The intersections in the plan above give all that is necessary to obtain the pattern of the cylinder, which can be done as follows: Lay off a stretchout of the profile U' V' opposite the end S² T², through the points in which draw the usual measuring lines. Place the T-square at right angles to the same, and, bringing it against the points in the miter line L M (or the points of intersection in *x y* in the plan from which L M was obtained), cut the corresponding measuring lines. Then a line traced through these points, as shown from L' to M', will be the shape of the pattern of the cylinder to fit against the cone.

For the pattern of the cone proceed as follows: From each of the points in the miter line L M carry lines horizontally across, cutting the side A B of the cone, by means of which their distance from the apex A may be accurately measured; also through these points draw lines from the apex A cutting the base B K, continuing them vertically into the plan N R P O, as shown. It may be noted that the line from point 4 on L M falls at point 2 in the plan of the cone; likewise that the line from 3 on L M falls at 3 in the plan of the cone, while the line from 2 falls upon the plan of the cone at a point marked *a*. From any convenient point, as A² of Fig. 520, with a radius equal to A B, describe the arc B² K² B³, which in length make equal to the circumference of the plan of the cone, setting off in the same all the points of the plan, as indicated by the figures and letters, and from these points draw lines toward the center A², all as shown. From A² as center, with radii corresponding to the distances A L, A 2, A 3, A 4 and A M of the elevation, strike arcs intersecting corresponding lines just drawn. Then a line traced through the intersections thus obtained will be the shape of the opening to be cut in the envelope of the cone to fit the end of the cylinder.

PROBLEM 160.

The Patterns of a Cylinder Joining the Frustum of a Cone in which the Axis of the Cylinder is Neither at Right Angles to the Axis Nor to the Side of the Cone.

The principles involved in the solution of this problem are exactly the same as those of the problem immediately preceding, to which the reader is referred for a more full explanation of the operation. The detailed or conditions differ only in the angle at which the cylinder joins the side of the cone.

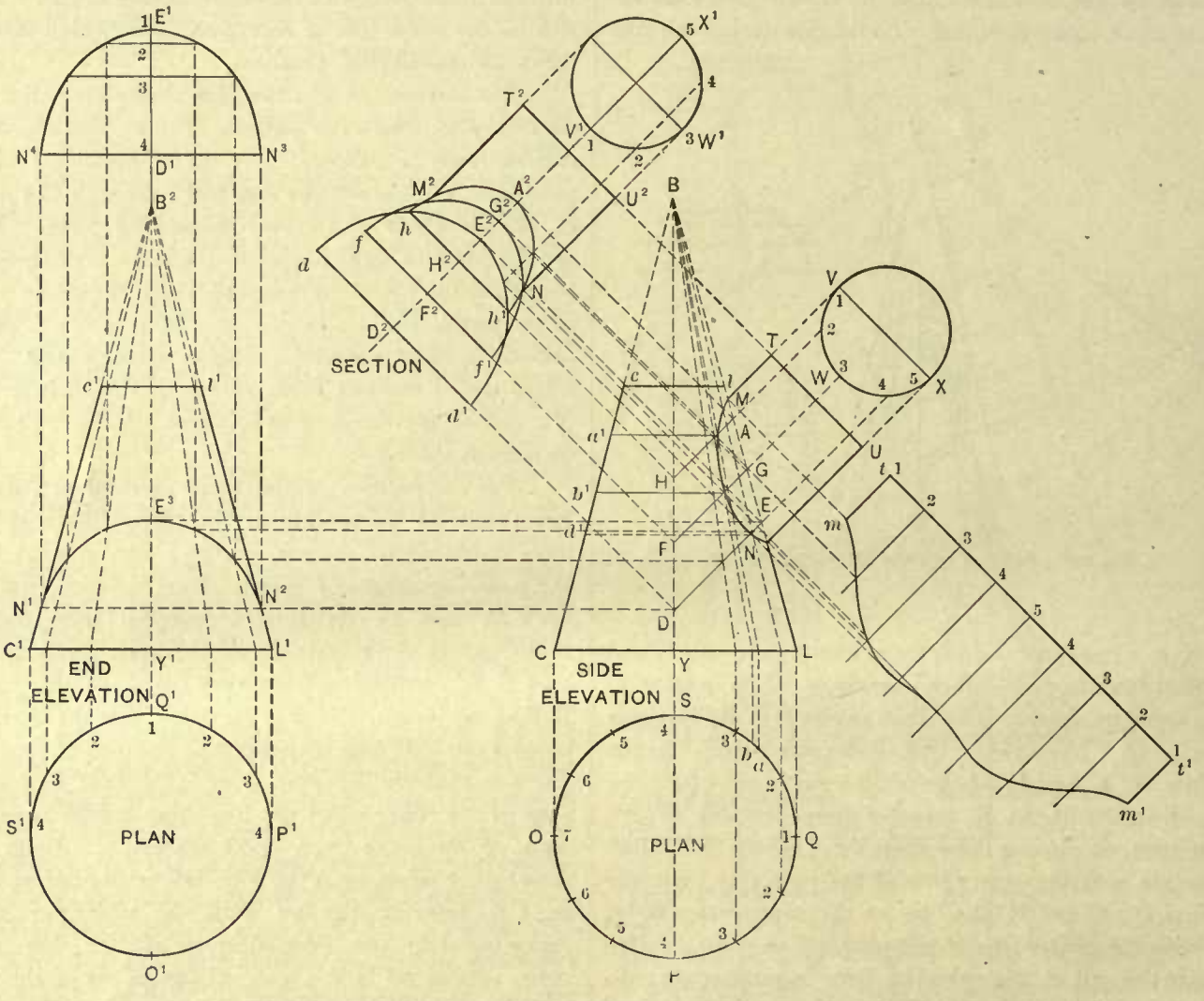


Fig. 521.—A Cylinder Joining the Frustum of a Cone at an Oblique Angle.

In Fig. 521, let C B L be the elevation of a right cone of which C *c l* L is a frustum, and let M T U N represent the cylinder which is to join the frustum, making the angle U N L greater than a right angle. The first operation will be to determine the shape of miter line M N of side elevation. Draw V W X, the section of the cylinder, which divide into any convenient number of equal parts, as indicated by the small figures, and from these points carry lines parallel with N X cutting the side B L of the cone in the points A, G and E, producing them until they cut the axis B Y in the points H, F and D. Draw a plan under the side elevation of cone, as shown by O S Q P, which divide into any convenient number of equal parts. From points 1 to 4 in S Q P carry lines vertically to the base C L, and thence toward the apex B, cutting the lines D E, F G and H A.

Draw a second elevation of the cone, as shown by

C¹ B² L¹, which represents the cone as turned quarter way round. Draw a corresponding plan under the end elevation, as shown by S¹ Q¹ P¹ O¹. Divide this plan into the same number of equal parts, commencing to number them at the same point as in the other plan—that is, at the point Q. From the points 1 to 4 inclusive in S¹ Q¹ P¹ of plan carry vertical lines to the base C¹ L¹, and thence to the apex B².

The next step is to construct sections of the cone as it would appear if cut upon the planes represented by the lines H A, F G and D E. For this purpose place the T-square at right angles to the axes of the two cones, and, bringing it against the points of intersection of the lines from the base C L with D E, cut corresponding lines in the second elevation, and

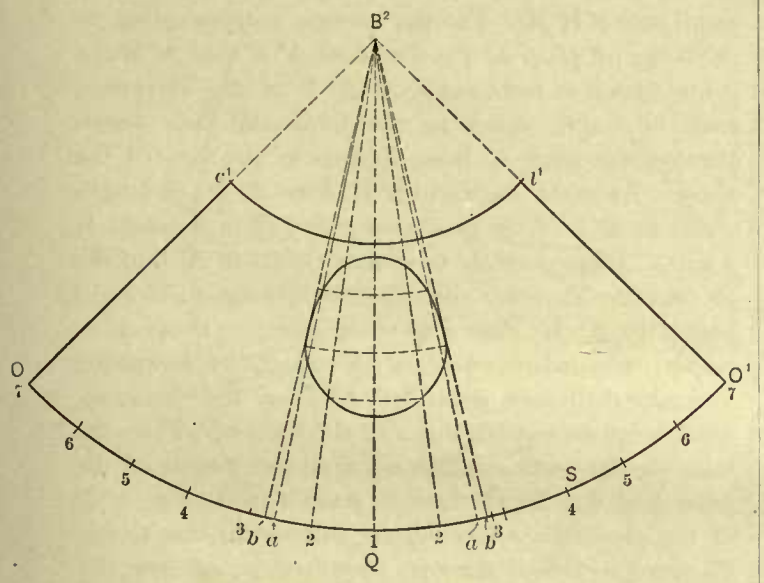


Fig. 522.—Envelope of Cone Shown in Fig. 521.

through the points of intersection thus established trace a line, as shown by N¹ E² N².

Continue the axis Y¹ B² as may be convenient, upon which set off spaces equal to those between the points in D E, and through these points draw lines at right angles to D¹ E¹. Place the T-square parallel to the axis Y¹ B², and, bringing it against the several points in N¹ E² N², cut the lines drawn through D¹ E¹, as shown, and through these points of intersection trace a line, as shown by N⁴ E¹ N³. Then N⁴ E¹ N³ is a section of the cone as it would appear if cut on the line D E. Sections corresponding to F G and H A can be obtained in a similar manner.

Having obtained sections of the cone corresponding to the several lines D E, F G and H A, it will next be necessary to project a plan at right angles to the axis of the cylinder, in which each of these sections shall find its place. Therefore, from all the points of the cylinder and of its intersections with the sides and axis of the cone project lines at right angles to N X indefinitely, through which at any convenient point draw a line, as D² X¹, parallel to N X. Upon this line, as a center of the plan about to be constructed, place the oblique sections just obtained so that each may be in line with the line in the elevation which it represents, and their center lines shall all coincide with D² X¹, all as shown. Make T² U² equal to T U and complete the plan of the cylinder, opposite the end of which draw a profile, as indicated by V¹ W¹ X¹, commencing the divisions at the point V¹. From the several points in the profile V¹ W¹ X¹ drop lines parallel with the center line D² X¹ against the several profiles *d* E² *d*¹, *f* G² *f*¹ and *h* A² *h*¹, and thence drop the points back on the elevation, cutting corresponding lines in it. Thus, from the intersection of the line drawn from point W¹ (3) with G² *f*¹ of section cut the line F G, which in the elevation corresponds to the point 3 in the profile V W X. From the intersection of a line drawn from point 2 in V¹ W¹ with A² *h*¹ of section cut the line H A, and so on, as indicated by the dotted lines. A line traced through these points of intersection, as shown by the curved line M N, will be the miter line in elevation, from which the patterns can be obtained as follows:

For the pattern of cylinder shown in elevation by M T U N, on T U extended lay off a stretchout of profile V W X, through the points in which draw the usual measuring lines. Place the T-square parallel with T U, and, bringing it against the points in the miter line M N, cut measuring lines of corresponding number. Trace a line through the points thus obtained, as shown from *m* to *m*′. Then *m t t*′ *m*′ is the pattern of the cylinder to fit against the cone, as shown in elevation by M T U N.

To obtain the pattern of the frustum carry lines from each of the points in the miter line M N horizontally across the elevation, cutting the side of the frustum *c* C, as shown by *a*¹, *b*¹ and *d*¹; also through the same points draw lines from the apex B, cutting the base line C L, and thence drop them on the plan, as shown by 1, 2, *a* and *b*. From any convenient point, as B² in Fig. 522, as a center, with radii equal to B *c* and B C, describe ares, as shown by O Q O¹ and *c*¹ *l*¹. Make O Q O¹ equal in length to the plan of cone O S Q P and upon it set off each way from the point Q

spaces equal to those upon the plan between Q and S. From these points draw lines indefinitely toward the center B^2. With B^2 as center describe arcs whose radii correspond to B M, B a^1, B b^1, B d^1 and B N, cutting lines of corresponding number or letter. Then a line traced through the intersections thus obtained will be the shape of opening to cut in the envelope of frustum where it joins the cylinder, and lines drawn from O and O^1 toward B^2 till they cut the arc c^1 l^1 in the points c^1 and l^1 will complete the pattern of the frustum.

PROBLEM 161.

The Patterns of Two Cones of Unequal Diameter Intersecting at Right Angles to their Axes.

Let U T V in Fig. 523 be the elevation of a cone, at right angles to the axis of which another cone or frustum of a cone, O F G P, is to miter. Let L K N M be a section of the frustum on the line F G. Let U^2 W V^2 be a half plan of the larger cone at the base. The first step in describing the patterns is to obtain the miter line in the elevation, as shown by the curved line from O to P. With this obtained the development of the pattern is a comparatively simple operation.

To obtain the miter line O P proceed as follows: Divide the profile L K N M into any convenient number of equal parts, as shown by the small figures. Inasmuch as the divisions of this profile are used in the construction of the sections—or, in other words, since sections through the cone must be constructed to correspond to certain lines through this profile—it is desirable that each half be divided into the same number of equal parts, as shown in the diagrams. Thus 2 and 2, 3 and 3, 4 and 4 of the opposite sides correspond, and sections, shown in the upper part of the diagram, are taken upon the planes which they represent. From the points in the profile L K N M draw lines parallel to B E cutting the end F G of the frustum. Produce the sides O F and P G until they meet in E, which is the apex of the cone. Through the points in F G draw lines from E, producing them until they cut the axis of the cone, as shown at A, A^1, A^2.

Next construct sections of the cone as it would appear if cut through upon the lines A C, A^1 B, A^2 D. Divide the plan U^2 W V^2 into any convenient number of parts. From the points thus established carry lines vertically to the base line U V, and thence carry them toward the apex T, cutting the lines A C, A^1 B, A^2 D, all as shown. Through each of the several points of intersection in these lines draw horizontal lines from the axis of the cone to the side, all as shown. At right angles to the lines A C, A^1 B, A^2 D project lines to any convenient point at which to construct the required sections. Upon the lines drawn from the points A, A^1, A^2 locate at convenience the points A^3, A^4, A^5. Inasmuch as A^1 B is at right angles to the axis of the cone, the section corresponding to it will be a semicircle whose radius will be equal to A^1 B. Therefore, from A^3 as center, with radius A^1 B, describe the semicircle S B^1 R. For the section corresponding to A^3 D lay off from A^5 the distances A^5 S^2 and A^5 R^2, in a line drawn at right angles to A^3 D of the elevation, each in length equal to the horizontal line drawn through the point A^3 from the axis to the side of the cone. At right angles to S^2 R^2 draw A^5 D^1, in length equal to A^3 D of the elevation. Set off in it points 5, 4 and 2, corresponding to similar points in A^3 D of the elevation. Through these points 5, 4 and 2, at right angles to A^5 D^1, draw lines indefinitely. From A^5 as center, with radius equal to the length of horizontal line passed through point 5 in A^3 D of the elevation, describe an arc cutting line 5 of the section. From the same center, with a radius equal to the length of the horizontal line drawn through point 4 in the line A^3 D of the elevation, strike an arc cutting the line 4, etc. Then a line traced through these points, as shown by S^2 D^1 R^2, will be the section of the cone as it would appear if cut on the line A^3 D of the elevation. In like manner obtain the section S^1 C^1 R^1, corresponding to A C of the elevation.

These sections may, if preferred, be obtained in the manner described in connection with Problems 159 and 160.

As these sections are obtained solely for the purpose of determining at what point in their perimeters—that is, at what distance from points C^1, B^1 and D^1—they will be intersected by the lines representing the points 2, 3 and 4 of the profile L K M N, it is not necessary that the complete half sections should be developed. In the engraving, the small intersecting cone has so little flare that the lines A C and A^3 D cross the large cone so nearly at right angles to its axis that sections 2 2 and 4 4 could be constructed with sufficient accu-

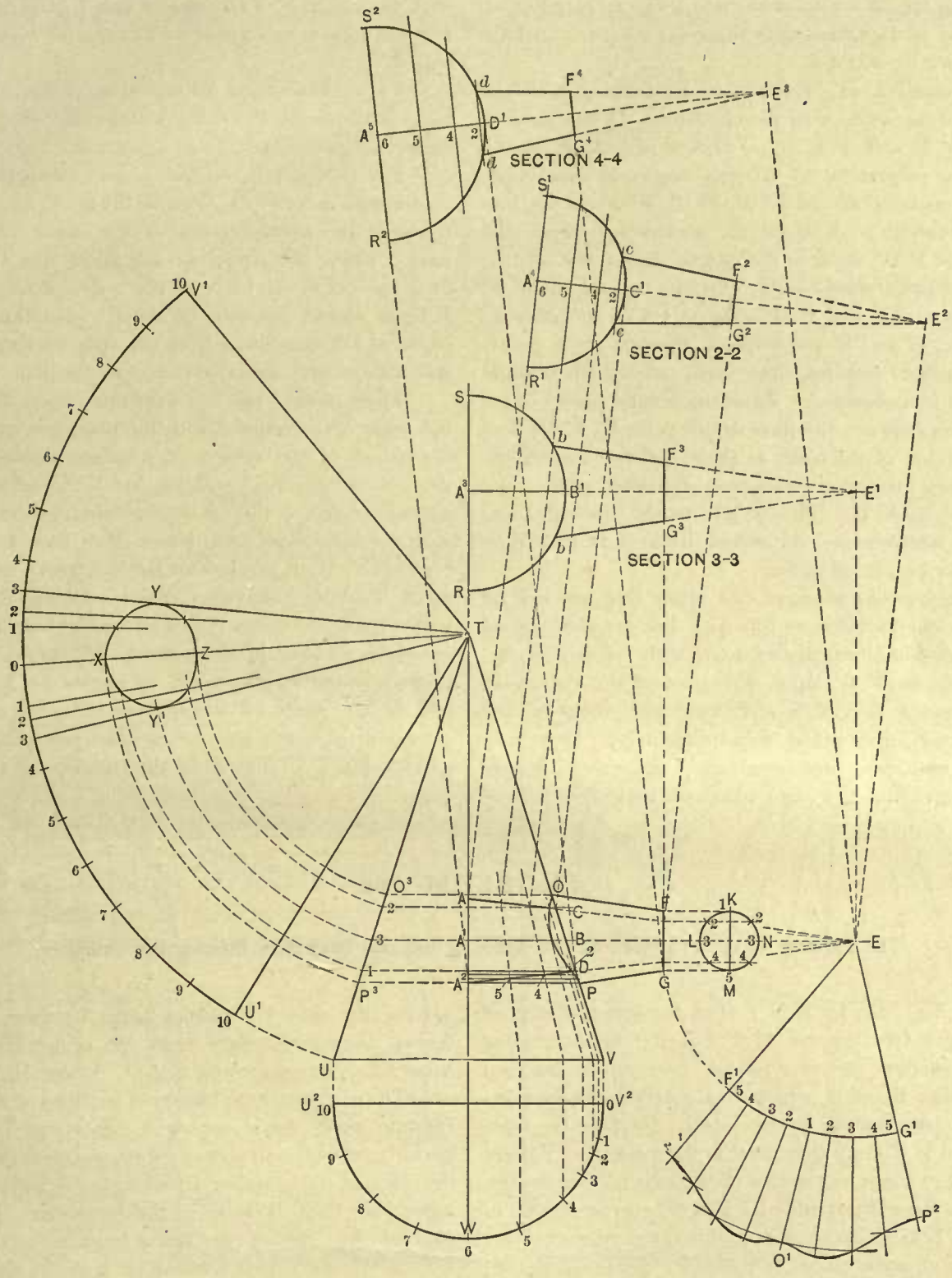


Fig. 523.—The Patterns of Two Unequal Cones Intersecting at Right Angles to their Axes.

racy for practical purposes, as in the case of section 3 3, by small arcs of circles with radii respectively equal to A C and A^2 D, and of only sufficient length to include the points *c c* and *d d*.

Prolong A^5 D^1, as shown by E^5, making A^5 E^5 in length equal to A^1 E of the elevation. In like manner make A^1 E^5 and A^2 E^1 equal to A E and A^1 E of the elevation respectively. At right angles to these lines in the sections set off F^5 G^5, F^3 G^3, F^1 G^4, in position corresponding to F G of the elevation. Make the length of F^2 G^2 equal to the length across the section of the frustum marked 2 2. In like manner make F^3 G^3 equal to 3 3, and F^1 G^4 equal to 4 4 of the section. From E^1, E^2 and E^3 respectively, through these points in the several sections, draw lines cutting the oblique sections just obtained. From the several points of intersection between the lines drawn from E^1, E^2, E^3 and the sections of the cone, as shown by *d d*, *c c* and *b b*, carry lines back to the elevation, intersecting the lines A C, A^1 B, A^2 D. Then a line traced through these several intersections, as shown from O to P, will be the miter line in elevation.

Having thus obtained the miter line, proceed to describe the patterns, as follows: For the envelope of the small cone, from E as center, with radius E G, describe the arc F^1 G^1, upon which set off the stretchout of the section L K M N. Through the points in this arc, from E, draw radial lines indefinitely. From E as center, with radii corresponding to the several points in the miter line O P, but obtained from the oblique sections above, cut corresponding radial lines. Thus with the radius E^3 *d* cut lines 4 and 4, with the radius E^2 *c* cut lines 2 and 2 and with radius E^1 *b* cut lines 3 and 3.

Then a line traced through these points of intersection, as shown by P^1 O^1 P^2, will be the shape of the pattern of the frustum to fit against the larger cone.

For the pattern of the larger cone, from T as center, with radius T U, describe the arc V^1 U^1, in length equal to the circumference of the entire plan of the cone. From the points in the miter line O P carry lines parallel to the base of the cone cutting its side T U, as shown between O^3 and P^3, also through the points in O P draw lines from the apex cutting the base and thence carry them vertically to the plan.

These points can be numbered upon the side of the cone to correspond with the plan, but entirely independent of the system of numbers employed upon the smaller cone. Upon the arc V^1 U^1 set off points corresponding to the points just obtained in the plan from the miter line, from which draw lines toward the center T. With one foot of the compasses set at the point T, bring the pencil point successively to the points between O^3 and P^3 and cut radial lines of corresponding number in the pattern. Then a line traced through these intersections, as shown by X Y Z Y^1, will be the shape of the opening to be cut in the envelope of the larger cone, over which the smaller cone will fit, and T U^1 V^1 will be the envelope of the entire cone.

PROBLEM 162.

The Patterns of the Frustums of Two Cones of Unequal Diameters Intersecting Obliquely.

In Fig. 524, let M N P O be the side elevation of the larger frustum and F^1 G^1 S R the side elevation of the smaller, the two joining upon a line between the points R and S, which line must be obtained before the patterns can be developed. Produce the sides S G^1 and R F^1 until they meet in the point E. At any convenient place on the line of the axis of the smaller frustum draw the profile H F K G, corresponding to the end F^1 G^1. Divide this profile into any convenient number of equal parts, as shown by the small figures 1, 2, 3, etc., and from these divisions, parallel to the axis of the cone, drop points on to F^1 G^1. From the apex E, through these points in F^1 G^1, carry lines cutting the side F P of the larger frustum, and producing them until they meet the center line, or the base O P, all as shown by B A, C A^1 and D A^2.

The next step is to construct sections of the larger frustum as it would appear if cut on each of these lines, from which to obtain points of intersection with the lines of the smaller frustum for determining the miter line from R to S in the elevation. Draw the plan of the base of the larger frustum, as shown by T U V W, and divide one-half of it in the usual manner. From these points carry lines vertically to the base O P of the frustum. Produce the sides O M and P N until they meet in the point L. From the points

in the base line obtained from the plan carry lines toward the apex L, cutting the section lines A B, project lines at right angles cutting A^3 B^1, as shown, in the points 4, 3 and 2. In like manner make A^4 C^1

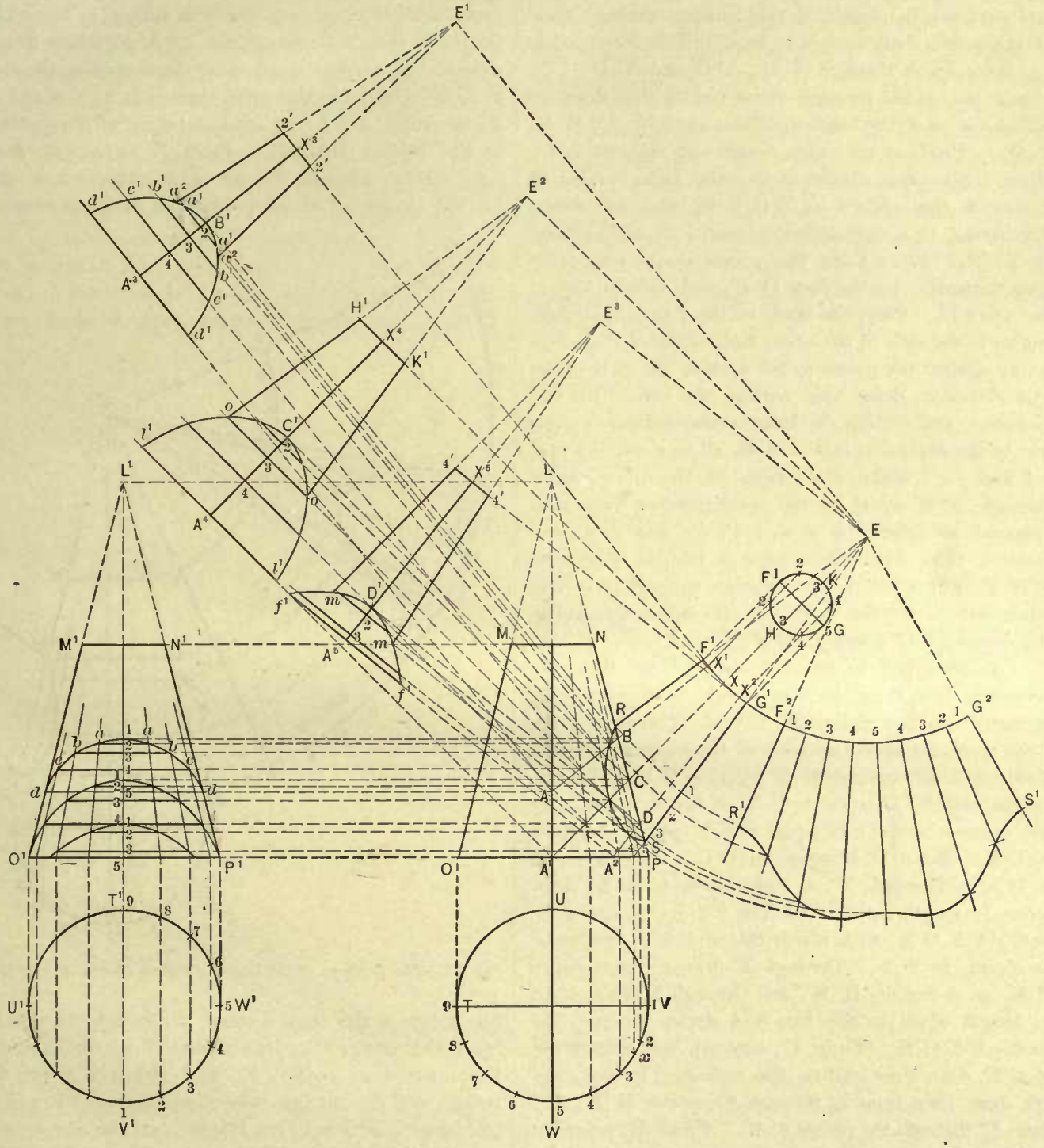


Fig. 524.—Patterns of the Frustums of Two Unequal Cones Intersecting Obliquely.

A^1 C and A^2 D, as shown. Parallel to A B and of the same length, at any convenient point outside of the elevation, draw A^3 B^1, and from the points in A B equal and parallel to A C, and from the points in A C project lines at right angles to it, cutting it as shown, giving the points 4, 3 and 2. Also make A^5 D^1 equal

to the section line A^3 D of the elevation, and cut it by lines from the points in A^3 D, obtaining the points 3 and 2, as shown. In order to complete these several sections, the width of the frustum through each of the points indicated is to be set off on corresponding lines drawn through A^3 B^1, A^4 C^1 and A^5 D^1. To obtain the width through these points first draw an end elevation of the larger frustum, as shown by M^1 N^1 P^1 O^1. Produce the sides, obtaining the apex L^1. Draw a plan and divide it into the same number of spaces as that shown in T U V W, and commence numbering at a corresponding point, all as indicated by V^1 U^1 T^1 W^1. From the points in the plan carry lines vertically to the base O^1 P^1, and thence toward the apex L^1. Place the blade of the T-square at right angles to the axis of the cone, and, bringing it successively against the points in the section line A B in the side elevation, draw lines cutting the axis of the end elevation, and cutting the lines corresponding in number to the several points in A B, all as shown by *a a*, *b b* and *c c*. Make the length of the lines drawn through A^3 B^1 equal to the corresponding lines thus obtained, as shown by a^1 a^1, b^1 b^1, c^1 c^1 and d^1 d^1, and through these extremities trace a line, as shown by d^1 B^1 d^1, which will be the section through the cone when cut on the line A B. In like manner complete the sections l^1 C^1 l^1 and f^1 D^1 f^1.

As remarked in the previous problem, it is only necessary that these sections should be developed far enough from the points B^1, C^1 and D^1 to receive the lines representing the sections of the smaller frustum. Produce A^3 B^1, making B^1 E^1 equal to B E of the elevation, and B^1 X^2 equal to B X^1 of the elevation. In like manner make C^1 E^2 equal to C E, and C^1 X^1 equal to C X. Make D^1 E^3 equal to D E, and D^1 X^5 equal to D X^2. Through X^3, at right angles to B^1 E^1, draw a line in length equal to the line 2 2 drawn across the profile F K G H, with which this section corresponds, as shown by 2′ 2′. Through X^4 draw a line equal to H K, as shown by H^1 K^1, and through X^5 draw 4′ 4′, in length equal to the line 4 4 drawn through the profile F K G H. From E^1, through the extremities of 2′ 2′, draw lines cutting the section. In like manner draw lines from E^2 through the points H^1 K^1, and from E^3 through the points 4′ 4′. From the points at which these lines meet the sections, as a^2 a^2 in the first, *o o* in the second and *m m* in the third, carry lines back at right angles to and cutting the corresponding section lines in the elevation. A line traced through the points thus obtained, as shown by R S, is the miter line in elevation formed by the junction of the two frustums.

Having thus obtained the miter line in elevation, proceed to develop the patterns as follows: From the points in R S, at right angles to A^1 E, which is the axis of the smaller cone, draw lines cutting the side E S, as shown by the small figures 1, 2, 3, 4 and 5. These points are to be used in laying off the pattern of the smaller frustum. From E as center, with radius E G^1, describe the arc F^2 G^2, upon which step off the stretchout of the profile F K H G, numbering

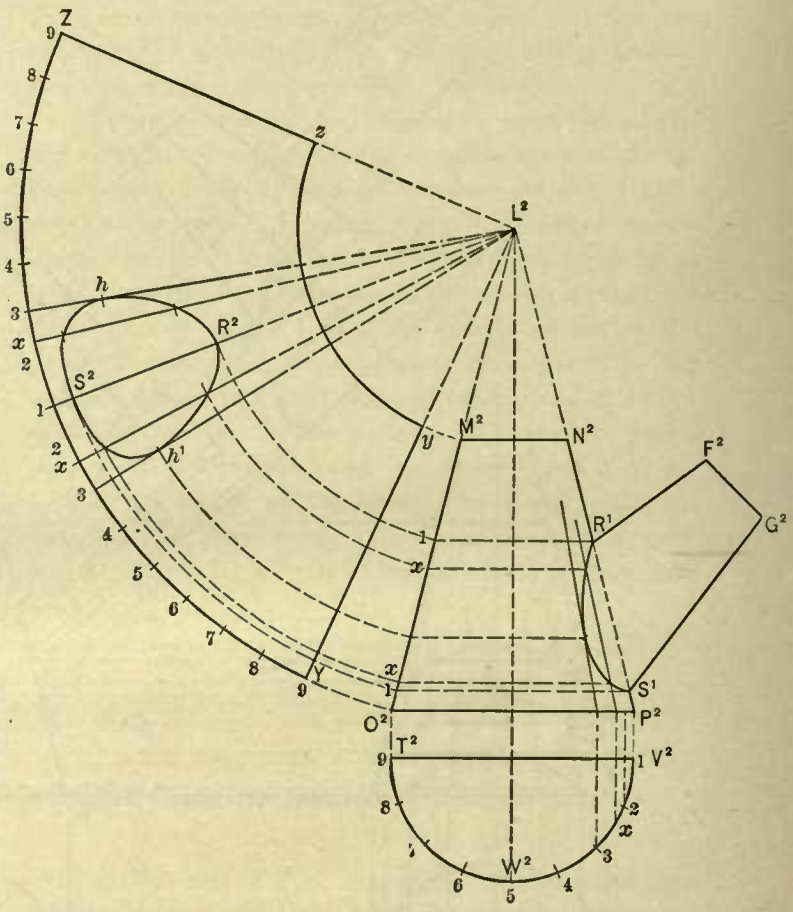


Fig. 525.—The Envelope of the Larger Frustum Shown in Fig. 524.

the points in the usual manner. Through the points, from the center E, draw radial lines indefinitely. From the same center, E, with radius E 1 (of the points in E S), cut the radial line numbered 1, and in like manner, with radii E2, E3, etc., cut the corresponding numbers of the radial lines. A line, R^1 S^1, traced through the several points of intersection thus formed will be the larger end of the pattern for the small frustum, thus completing the shape of that piece, all as shown by R^1 S^1 G^2 F^2.

To avoid confusion of lines, the manner of obtaining the envelope of the large frustum is shown in Fig. 525, which is a duplicate of the side elevation and plan shown in Fig. 524, the miter line R^1 S^1 and the points in it being the same. Similar letters refer to corresponding parts in the several figures. From L^2 as center, with radius L^2 O^2, describe an arc, as shown by Y Z, and from the same center, with radius L^2 M^2, describe a second arc, as shown by *y z*. Draw Y *y*, and upon Y Z lay off the stretchout of the plan V^2 W^2 T^2, all as shown. Draw Z *z*. Then Z *z y* Y will be the envelope of the large frustum. Through the points in the miter line R^1 S^1 draw lines from the apex of the cone to the base, and from the base continue them at right angles to it until they meet the circumference of the plan. Mark corresponding points in the stretchout Y Z, and insert any points which do not correspond with points already fixed therein. From each of the points thus designated draw a line across the envelope already described to the apex, as shown by 3 L^2, *x* L^2 and 1 L^2. Also, from the points in the miter line R^1 S^1 draw lines at right angles to the axis of the frustum cutting the side L^2 O^2, as shown. From L^2 as center describe arcs corresponding to each of these points and cutting the radial lines drawn across the envelope of the cone. A line traced through the points of intersection between arcs and lines of the same number, as shown by *h* R^2 h^1 S^2, will be the shape of the opening to fit the base of the smaller frustum.

SECTION 3.

Irregular Forms.

(TRIANGULATION.)

The class of subjects treated in this section will include all irregular forms which can be constructed from sheet metal by simple bending or forming, but whose patterns cannot be developed by the regular methods employed in the two previous sections of this chapter. These problems divide themselves naturally, in regard to the arrangement of the triangles used in the development of the patterns, into two classes, viz.: First, those in which the vertices of the triangles used in constructing the envelopes all terminate at a common point or apex, and, second, those in which the relative position of the base and the vertex is reversed in each succeeding triangle, or, in other words, those in which the vertices of alternate triangles point in opposite directions.

In the introduction to Section 2 (page 240), attention is called to the difference between a scalene or oblique cone and a right cone with an oblique base. The scalene cone may be called the type or representative of a large number of forms belonging to the first class above mentioned, since many rounded surfaces entering into the construction of various irregular flaring articles are portions of the envelope of a scalene cone. The principles involved in this particular class of forms are explained in that part of Chapter V referring to Fig. 271, page 94.

Inasmuch as *triangulation* is resorted to in all cases where regular methods are not applicable, it is not surprising that the forms here treated, especially those included in the second class above referred to, are more varied in character than those of any other class to be met with in pattern cutting. An explanation of methods and principles governing these will be found in the third subdivision of Chapter V, beginning on page 86. The last few problems of this class are devoted to the development of the horizontal surfaces of arches in circular walls.

The arrangement of problems in this section will be in accordance with the above classification although no headings will be introduced to distinguish the classes.

PROBLEM 163.

The Envelope of a Scalene Cone.

In Figs. 526 and 527 are shown perspective representations of scalene or oblique cones. In Fig. 526 the inclination of the axis to the base is so great that a vertical line dropped from its apex would fall outside the base, while in Fig. 527 a perpendicular from its apex would fall at a point between the center and the perimeter of its base.

Supposing the circumference of the base in either case to be divided into a number of equal spaces, it is plain to be seen that lines drawn upon the surface of the cone from the points of division to the apex would be straight lines of unequal lengths, and that such lines would divide the surface of the cone into triangles whose vertices are at the apex of the cone and whose bases would be the divisions upon the base of the cone. It will be seen further that with the means at hand of determining the lengths of these lines forming the sides of the triangles, the pattern cutter possesses all that is necessary in developing their envelopes or patterns.

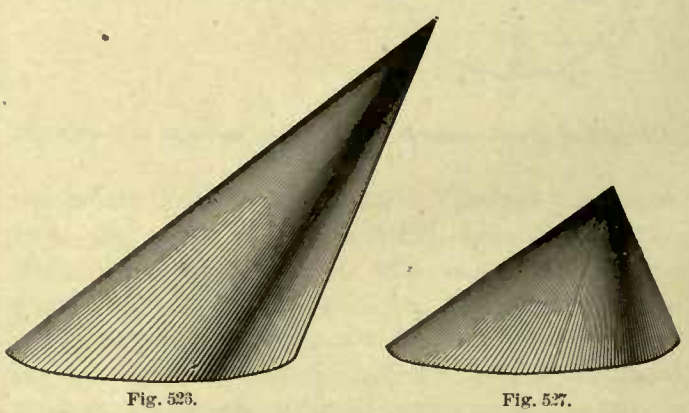


Fig. 526. Fig. 527.

Scalene Cones of Different Inclinations.

In Fig. 528, D A H is an elevation of the cone shown in Fig. 526 and D G H is a half plan of the

same, drawn for convenience, so that D H is at once the base line of the elevation and the center line of the plan. Fig. 529 shows an elevation and plan of the cone shown in Fig. 527, drawn in the same manner. The principle involved in the development of the patterns of the two oblique cones is exactly the same and, as will be seen, letters referring to similar parts in the two drawings are the same; therefore the following demonstration will apply equally well in either case.

From the apex A drop a perpendicular to the base

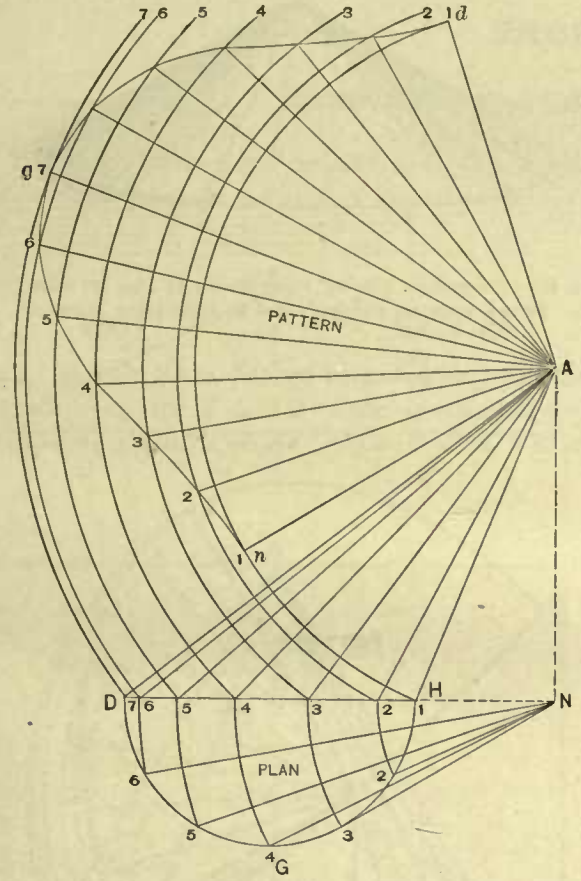


Fig. 528.—Pattern of Cone Shown in Fig. 526.

line, locating the point N. Divide the base D G H into any convenient number of equal spaces, as shown by the small figures, and from the points thus obtained draw lines to the point N. These lines will form the bases of a series of right angled triangles of which A N is the perpendicular hight, and whose hypothenuses when drawn will give the correct length of lines extending from the points of division in the base of the cone to the apex. The most convenient method of constructing these right angled triangles is to transfer the distances from N to the various points upon the circumference of the base to the line N D as a base line, measuring each time from the point N, by which method the line A N becomes the common perpendicular of all the triangles. Therefore from N as center, with the distances N 1, N 2, etc., as radii, describe arcs as shown in the engraving, cutting the base line N D. Lines from each of these points to the apex, as A 1, A 2, etc., will be the required hypothenuses.

The simplest method of developing the pattern is to first describe a number of arcs whose radii are respectively equal to the various hypothenuses just obtained; therefore place one foot of the compasses at A, and, bringing the pencil point successively to the

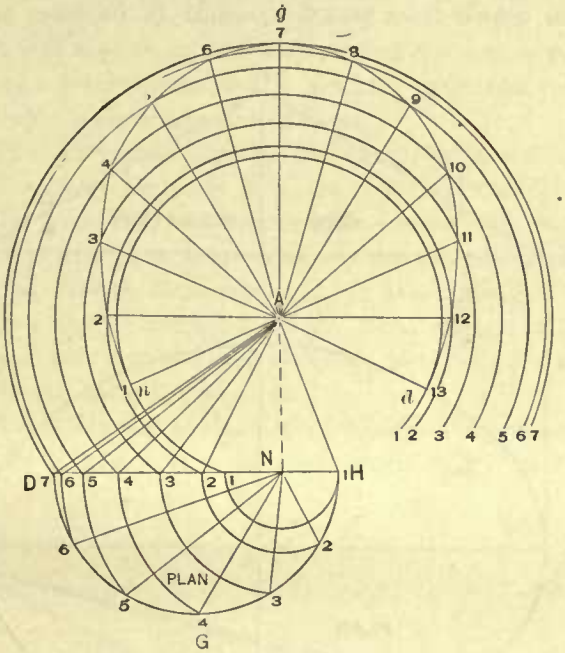


Fig. 529.—Pattern of Cone Shown in Fig. 527.

points 1, 2, 3, etc., upon the line N D, describe arcs indefinitely. From any point upon the arc drawn from point 1, as *n*, draw a line to A as one side of the pattern. Next take between the feet of the dividers a space equal to the spaces upon the circumference of the plan, and placing one foot of the dividers at the point *n*, swing the other foot around till it cuts the arc drawn from point 2; then A *n* 2 will be the first triangle forming part of the envelope or pattern. With the same space between the points of the dividers, and 2 of the pattern as center, swing the dividers around again, cutting the arc drawn from point 3. Repeat this operation from 3 as center, or, in other words, continue to step from one arc to the next, until all the arcs have been reached, as at *g*, which in this

case will constitute one-half the pattern; after which, if desirable, the operation of stepping from arc to arc may be continued, as shown, finally reaching the point *d*. Draw *d* A and trace a line through the points obtained upon the arcs, as shown by *n g d*, which will complete the pattern.

PROBLEM 164.

The Envelope of an Elliptical Cone.

In Fig. 530 is shown an elevation and plan of a cone whose base is an elliptical figure. So far as the solution of this problem is concerned the plan may be a perfect ellipse or an approximate ellipse drawn by any convenient method. Fig. 531 shows a perspective view of the cone in question, upon which lines have been drawn from points assumed in its base to the

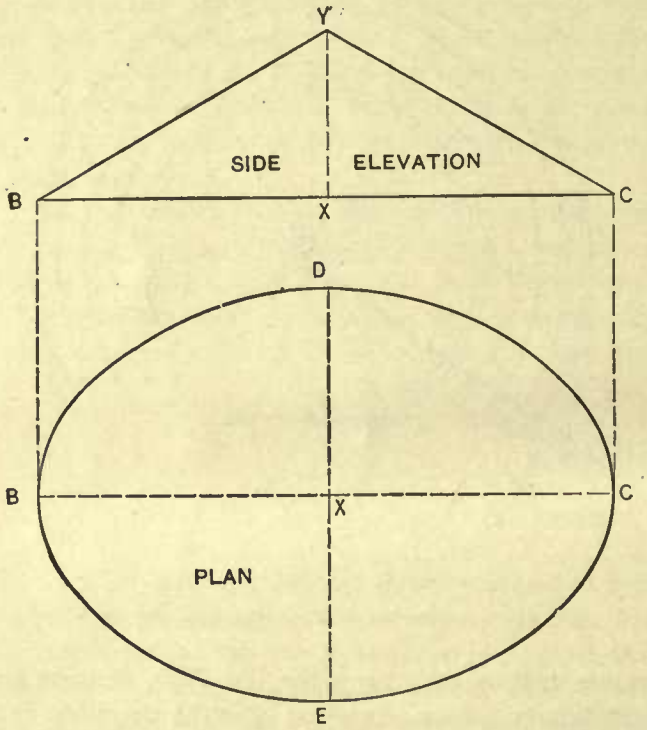


Fig. 530.—Plan and Elevation of Cone with Elliptical Base.

apex. From an inspection of this view it will appear that these lines, as in the case of the scalene cone, are of unequal length, and therefore that the pattern of its envelope may be developed by a method analogous to that adopted in the preceding problem.

Since the cone consists of four symmetrical quarters, it will be necessary to obtain the envelope of only one quarter, from which the remainder of the pattern can be obtained by reduplication. Therefore draw a half side elevation, as shown by Y X C of Fig. 532, immediately below which draw a quarter plan, X C E, so that the line X C shall be common to both views, as shown. Divide E C into any convenient number of

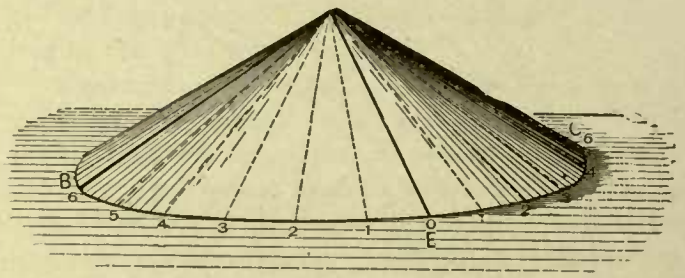


Fig. 531.—Perspective View of Cone Shown in Fig. 530 with Lines Drawn upon its Surface Used in Developing Pattern.

equal parts, as indicated by the small figures. Lines drawn from the points in E C to X will give the base lines of a set of triangles, whose altitudes are equal to

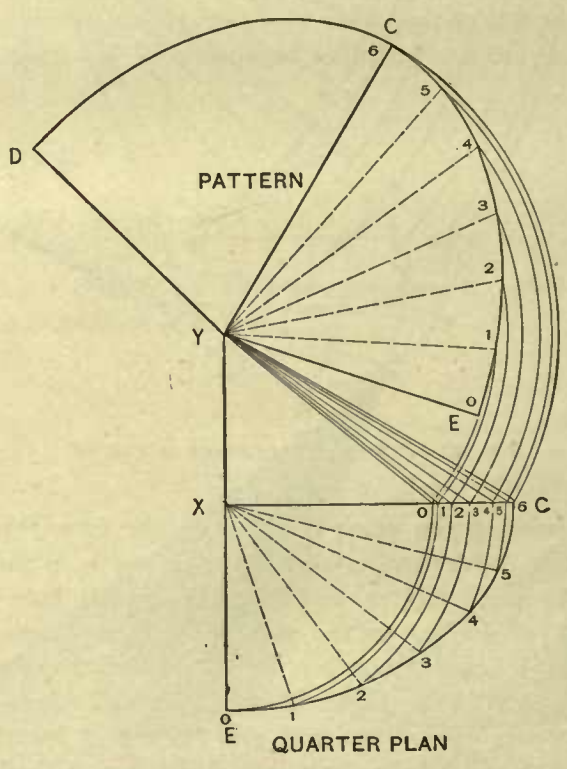


Fig. 532.—Pattern of One-Half the Cone Shown in Fig. 530.

the hight of the article X Y, and whose hypothenuses will give the true distances from the apex to the points

assumed in the base line. A convenient method for drawing these triangles is as follows: With X as center strike arcs from the points in E C, cutting X C, as shown by the small figures. Lines drawn from the points thus obtained to Y, as shown, will give the hypothenuses of the triangles. With Y as center, and the distance from Y to the several points in X C as radii, strike arcs indefinitely. From Y to any point upon the arc 0 draw any line, as Y E, which will form the edge of pattern corresponding to X E of plan. With the dividers set to the space used in stepping off E C of plan, and starting from E of the pattern, space off the stretchout of the plan, stepping from one arc to the next, as shown. From the point 6, or C', draw a line to Y. Through the points thus obtained trace a line. Then Y C E is the pattern for that part of the article shown on plan by E X C. This quarter can be duplicated by any means most convenient so as to obtain the pattern for one-half or for the whole envelope in one piece, as desired.

PROBLEM 165.

Pattern for a Raised Boiler Cover With Rounded Corners.

The shape of the cover considered in this problem may perhaps be more accurately described as that of

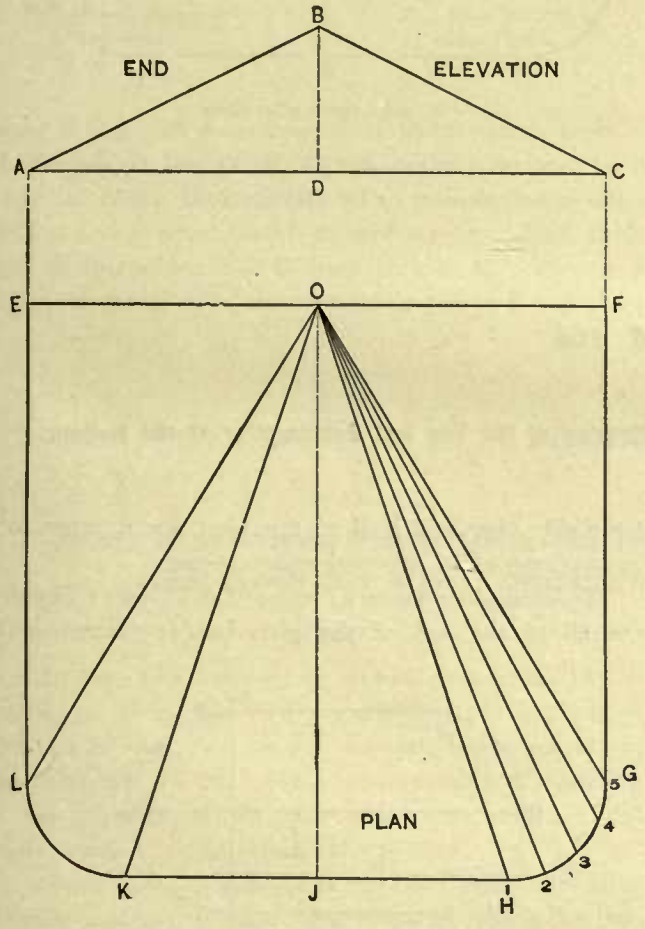


Fig. 533.—Plan and Elevation of Cover.

an oblong pyramid with rounded corners, as shown by the plan and elevation in Fig. 533, an inspection of which will also show that the rounded corners are portions of a scalene cone, while the four pyramidal sides are simply plain triangular surfaces.

The plan shows one-half of cover, or as much as would usually be made from one piece. First divide G H of plan into any convenient number of equal parts—in this case four—and connect the points thus obtained with O, thus obtaining the base lines of a set of right angled triangles whose hypothenuses when obtained will give the true distances from the points in G H to the apex of the cover.

To construct a diagram of triangles represented by lines in plan, draw the right angle M N P in Fig.

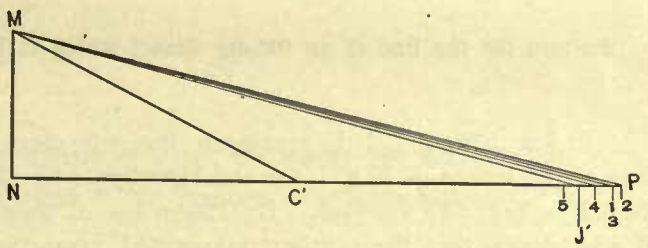


Fig. 534.—Diagram of Triangles.

534, making M N equal to the hight of cover, as shown by B D of elevation. Measuring from N, set off on N P the length of lines in plan, including J O and O F. From the points in N P draw lines to M, as shown. The line C' M gives the slant hight of cover as seen in the end elevation, and M J' the slant hight as would be seen in side elevation. The other lines give the hypothenuses of triangles, the bases of which are shown by the lines in O G H of plan.

To describe the pattern proceed as follows:

Draw the line Q U, in Fig. 535, in length equal to M J′ in the diagram of triangles. Through U, at right angles to Q U, draw V T, making U T and U V each equal to J H or J K of Fig. 533, and draw Q T and Q V. Then Q V T will be the pattern of one of the sides of the pyramid, to which may be added on either side the envelope of the portion of a scalene cone shown by H O G in Fig. 533. It should be here remarked that the method above employed of obtaining the length Q T produces the same results as that employed in the diagram of triangles as shown by the hypothenuse M 1, which is one side of the adjacent triangle forming part of the pattern of the rounded corner. From Q of Fig. 535 as center and M 2 of the diagram of triangles as radius strike a small arc, 2′, which arc is to be intersected with one struck from T of pattern and the distance H 2 of plan as radius. Proceed in this manner, using the spaces in H G of plan for the distances in T S of pattern, and the lengths of lines drawn from M to points 2 to 5 in diagram of triangles for the distances across the pattern from Q to the points in T S. With S of pattern as center, and G F of plan as radius, describe a small arc, R, which intersect with one struck from Q of pattern as center, and M C′ of the triangles or B C of the elevation as radius, thus establishing the point R of pattern. Draw R S, and trace a line through the points from S to T, as shown. The

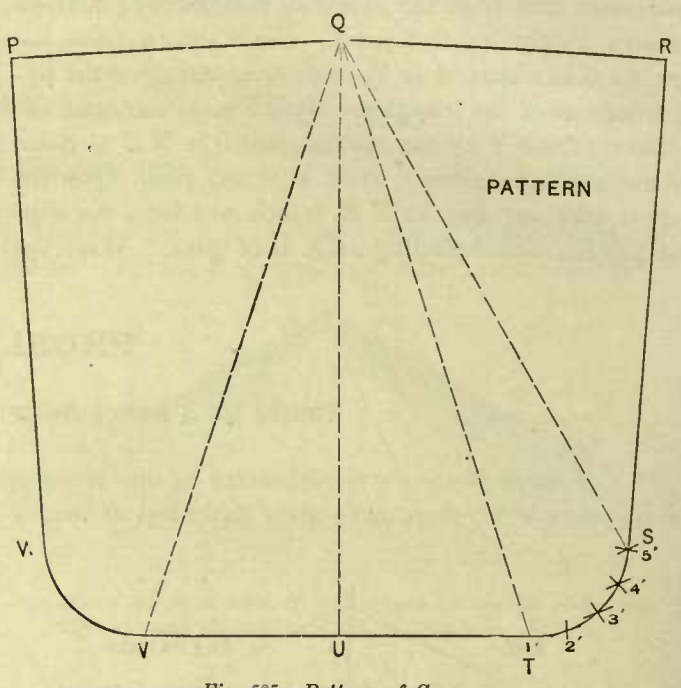


Fig. 535.—Pattern of Cover.

other part of pattern, as Q V W P, can be described in the same manner, or by duplication.

PROBLEM 166.

Pattern for the End of an Oblong Vessel which is Semicircular at the Top and Rectangular at the Bottom.

In Fig. 536, A C D E represents the side elevation of the article, F H K L the end elevation, and M N R P in Fig. 537 the plan. By inspection of these it will be seen that the portion represented upon the

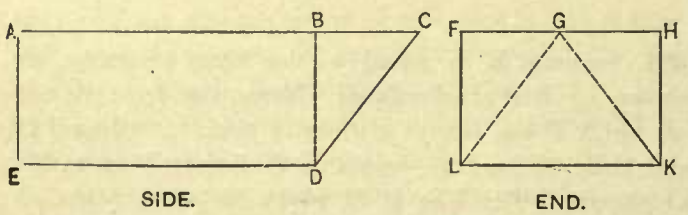


Fig. 536.—Side and End Elevations of Oblong Vessel with Semicircular End.

end elevation by G L K is simply a flat triangular surface, while the corners of the vessel, shown by B C D of the side view and N R of the plan, are quarters of the envelope of an inverted scalene cone.

To obtain the patterns proceed as follows: Divide one-half of the end of the plan into any convenient

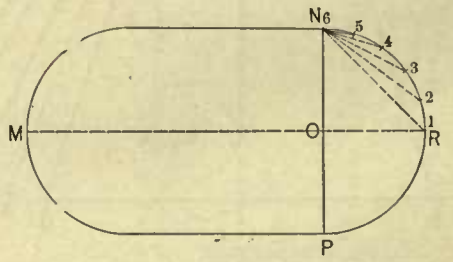


Fig. 537.—Plan of Oblong Vessel with Semicircular End.

number of equal spaces, all as shown by small figures 1, 2, 3, 4, etc., in N R. From each of the points thus

determined draw lines to the point N, the apex of the cone in plan, all as shown in the engraving. Proceed next to construct the diagram of triangles shown in Fig. 538, of which the lines just drawn in the plan are the bases and B D is the common altitude. Draw A B, in length equal to D B of Fig. 536, and at right angles to it draw B C, which produce indefinitely. From B

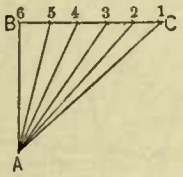


Fig. 538.—Diagram of Triangles.

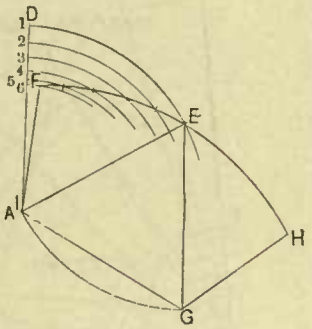


Fig. 539.—Pattern of End Pieces.

along B C set off spaces equal to the distances from N of the plan to the several points in the boundary line. That is, make B 5 of Fig. 538 equal to N 5 of Fig. 537, and B 4 equal to N 4, and so on. And from each of the points in B C draw lines to A. Then the distances from A to the various points in B C will be the distances from the apex of the scalene cone to the various points assumed in its base, and will be the radii of the arcs shown between D F and E in Fig. 539. For convenience erect any perpendicular, as A' D of Fig. 539, upon which set off distances equal to the length of the lines in the diagram drawn from A, or, in other words, make A' 1 equal to A 1 of the diagram, Fig. 538; A' 2 equal to A 2 of the diagram, and so on. From A' as center, with radius A' D, describe the arc D E indefinitely. In like manner, from the same center, with radius A' 2, describe a corresponding arc, and proceed in this way with each of the other points lying in the line A' D.

From any convenient point upon arc 6, as F, draw A' F, which will represent the side of the pattern corresponding to B D of the side elevation. With the dividers set to the space used in stepping off the arc N R of the plan, place one foot at the point F of the pattern and step from one arc to the next until all the arcs are reached, and draw A' E. Then A' F E will be one portion of the required pattern. From E as center, with radius E A', describe the arc A' G indefinitely. Make the chord A' G equal to L K of the end elevation, Fig. 536, and draw E G. Then A' E G will be the pattern of that portion shown by L G K of the end view and N R P of the plan. Duplicate the part A' F E, as shown by G H E, thus completing the pattern of the entire end.

PROBLEM 167.

Pattern of an Irregular Flaring Article, both Top and Bottom of which are Round and Parallel, but Placed Eccentrically in Plan; Otherwise the Envelope of the Frustum of a Scalene Cone.

In Fig. 540 is shown an elevation and plan of the article, in which E F G H is the plan of the bottom and E J K L that of the top, the two being tangent at the point E. In Fig. 541 the elevation and a portion of the plan are drawn to a larger scale and conveniently located for describing the pattern.

Since the top and the base of the article are both circular and are parallel, the shape of which the pattern is required becomes a frustum of a scalene cone, and lines drawn upon its surface from any set of points assumed in the circumference of its base to its apex will divide the circumference of the top into similar and proportionate spaces. Therefore, the first step is to extend the lines of the sides B A and C D until they meet at M, the apex. Next divide the plan of the base, one-half of which, E H G, only is shown, into any convenient number of equal spaces, as shown by the small figures. As it is necessary to ascertain the distance from each of these points to the apex of the cone the simplest method of accomplishing this is as follows: From E, the position of the apex in plan, as a center, with E 6, E 5, E 4, etc., as radii, describe arcs cutting E G. Carry lines vertically from each of the points in E G, cutting the base line A D; thence

carry them toward the apex M, cutting the line of the top B C, all as shown.

With M as center describe arcs from each of the points in the base line A D, and extend them indefinitely in the direction of O. In the same manner draw arcs from the points of intersection in B C, as shown. From the apex M draw any line to intersect the arc from A or 7 of the base line, as M N, which will form one side of the pattern, corresponding to B A of the elevation. Set the dividers to the space

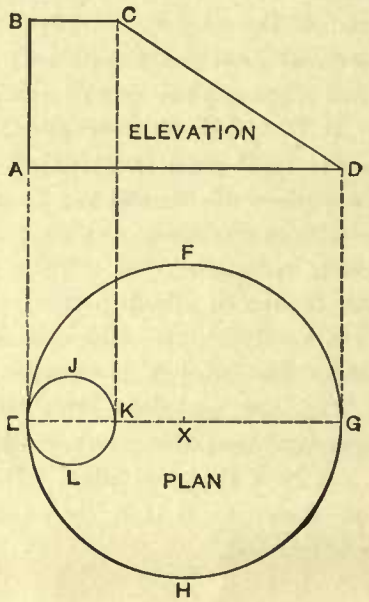


Fig. 540.—Plan and Elevation of Frustum of a Scalene Cone.

E 6, used in dividing the plan of the base, and starting from N step from one arc to the next, thus laying out the stretchout of the base E H G, and at the same time locating each point at its proper distance from the apex M. A line traced through these points, as N Q O, will be the bottom of one-half of the pattern. From the points in the line N Q O draw lines to M, cutting the arcs of corresponding number previously drawn from B C; then a line traced through these points of intersection, as shown by R P, will be the top

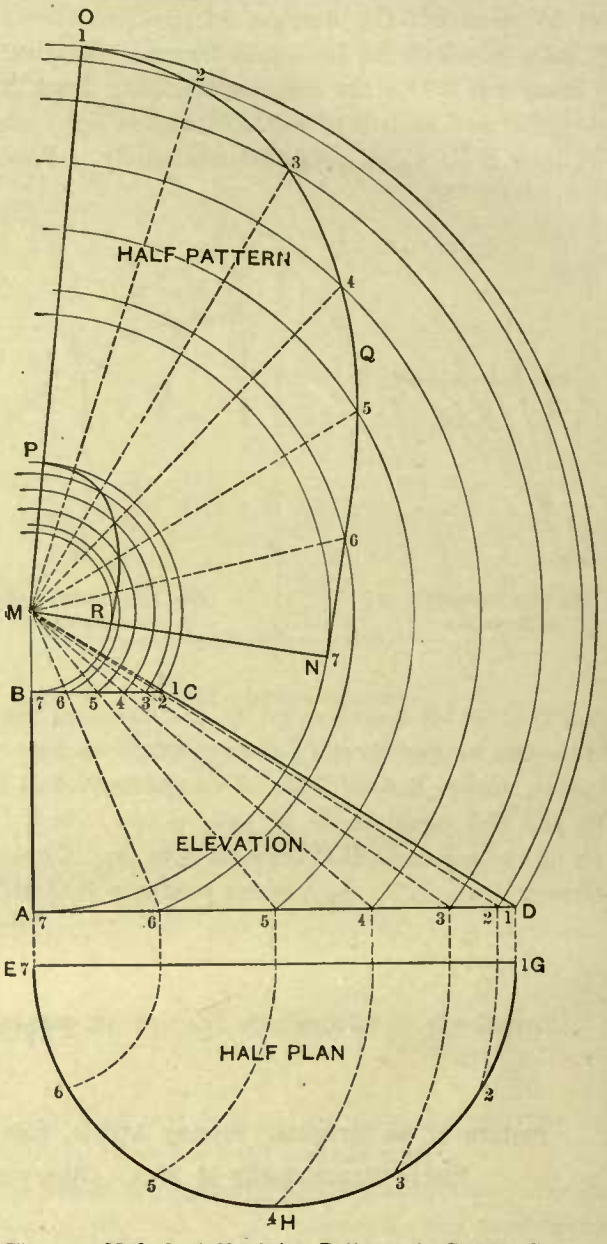


Fig. 541.—Method of Obtaining Pattern of a Scalene Cone.

of the pattern, and P R N Q O will thus be one-half the required pattern.

PROBLEM 168.

Pattern of a Flaring Article, the Top of which is Round and the Bottom Oblong with Semicircular Ends.—Two Cases.

First Case.—In Fig. 542 is shown the elevation and plan of the article drawn in proper relation to each other, as shown by the lines of projection. In this case the top of the article is located centrally with reference to the bottom, as shown in the plan. From O, the center of the top, erect the perpendicular O *o*, cutting

the line of the top in elevation, and from P erect the perpendicular P p, cutting the line of the base. Since L M N and F H G of the plan are semicircles lying in parallel planes, that part of the pattern of the article shown by L F H G N M must be one-half the envelope of the frustum of a scalene cone.

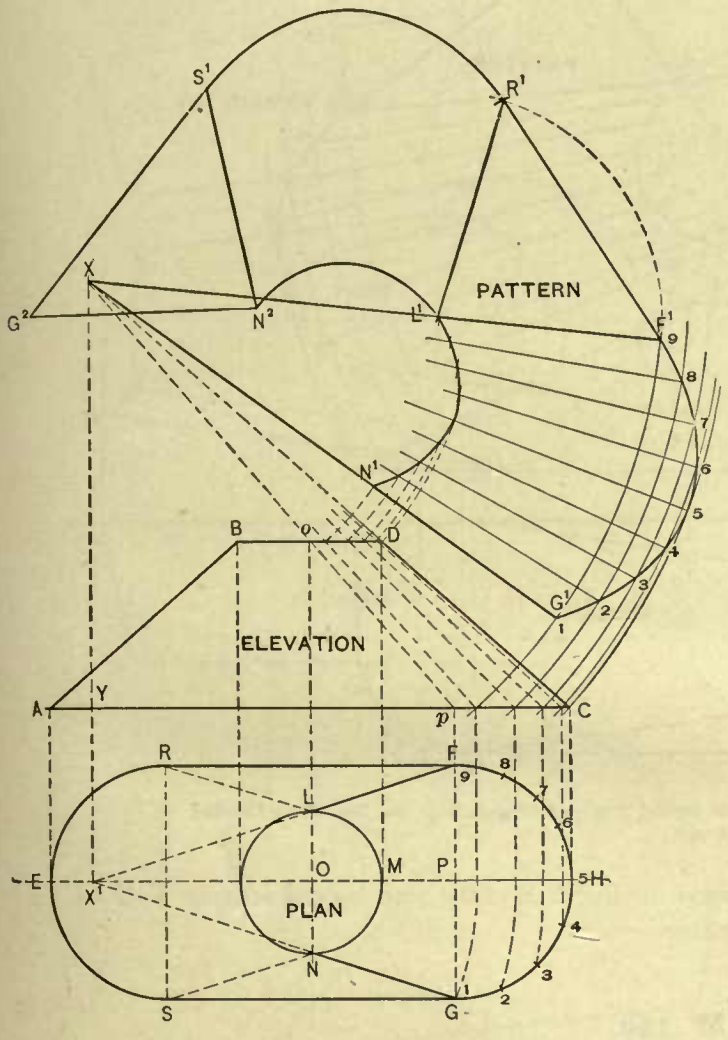


Fig. 542.—Plan, Elevation and Pattern of Flaring Article with Round Top and Oblong Base, the Top being Centrally Located.

To ascertain the apex of the cone, prolong the side line C D of the elevation indefinitely in the direction of X. Through the points p and o draw p o, which produce until it meets C D prolonged in the point X. Then X is the apex required. From X drop a perpendicular, cutting the center line of the plan at X', thus locating the apex in plan. Divide F H G into any convenient number of equal spaces, as shown by the small figures. Should lines be drawn from each of the points thus obtained to X', they would represent the bases of a set of right angled triangles, of which Y X is the common altitude, and whose hypothenuses will give correct distances from the apex of the cone to the various points assumed in the base.

The simplest method of obtaining these hypothenuses is as follows: From X' as center draw arcs from each of the points in F H G, cutting the center line E H of the plan. From each point in P H erect a perpendicular to p C, as shown. From the points thus obtained in p C carry lines toward the apex X, cutting o D, as shown. From X as center strike arcs from each of the points in p C indefinitely. Assume any point, as G', upon the arc struck from point 1 as the first point in the pattern of the base, from which draw a line to X. Set the dividers to the space used in stepping off the plan, and, commencing at G', step to the second arc, and from that point to the third arc, and so on, as shown in the engraving. A line traced through these points will be the boundary of a lower side of the semicircular end. From each of these points just obtained draw a line toward the center X. Place one foot of the dividers at X, and, bringing the pencil point successively to the points in o D, cut radial lines of corresponding number just drawn. A line traced through these points of intersection, as shown by N' L', will form the upper edge of the pattern of the end piece. From the point L', which corresponds to L of the plan, as center, with L' F' as radius, describe the arc F' R', and from F' as center, with radius equal to F R of the plan, intersect it at R', as shown. Draw L' R'. Then L' R' F' is the pattern of one of the sides. To L' R' add a duplicate of the end piece already obtained, all as shown by L' R' S' N², and to S' N² add a duplicate of the side just obtained, as shown by S' N² G², thus completing the pattern.

Second Case.—This case differs from the first only in the fact that the top of the article, being located near one end, is drawn concentric with the semicircle of the near end. As the result of this condition, that portion of its pattern shown by S E R L K N in the plan, Fig. 543, becomes one-half the envelope of the frustum of a right cone, the method of developing which is given in Problem 123 of the previous section of this chapter.

In that portion of the article shown by R F H G S N the conditions are exactly the same as in the first case. In Fig. 543 corresponding parts have been lettered the same as in Fig. 542, so that the demonstra-

tion given above is equally applicable to either figure. In the final make up of the various parts of which the complete pattern is composed, the part R¹ S¹ N² L¹ is of course obtained as in Problem 123 instead of being a duplicate of L¹ F¹ G¹ N¹, all as clearly shown in the engraving. The seam in this case has been located upon the line N S of the plan instead of upon N G as before.

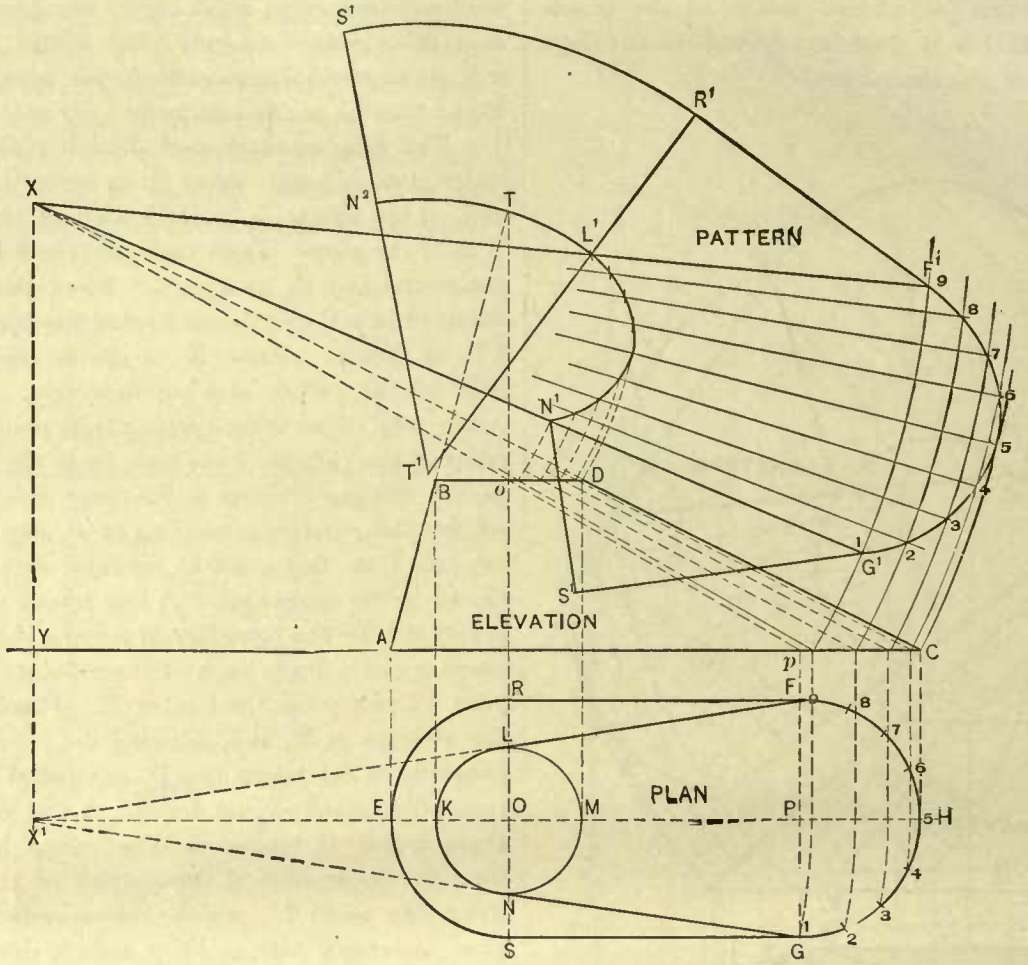


Fig. 543.—Plan, Elevation and Pattern of Flaring Article with Round Top and Oblong Base, the Top being Located near One End.

PROBLEM 169.

The Patterns of a Flaring Tub with Tapering Sides and Semicircular Head, the Head having More Flare than the Sides.

In Fig. 544, A B C D shows a side elevation of the tub, L M N O P the plan at the top, and E F G H K the plan at the bottom, an inspection of which will show that the head, as shown by H O or C D, has more flare than the sides, whose flare is shown by A J or A B, the flare of the sides and foot being the same. Inasmuch as the article is tapering in plan, the conical part of the pattern will include a little more than a semicircle, as shown. The points showing the junction between the straight sides and the conical part are to be determined by lines drawn from the centers by which the top and bottom were struck, perpendicular to the sides of the article. Therefore lay off in the plan T N and T P, drawn from the center T' of the curved part of the plan of the top of the article, perpendicular to the sides M N and L P respectively.

And in like manner from S, the center by which the curved part of the bottom of the article is struck, draw S G and S K.

Since the top and bottom of the tub are parallel, as shown by the side elevation, and their circles are not concentric in the plan, it follows that the part P O

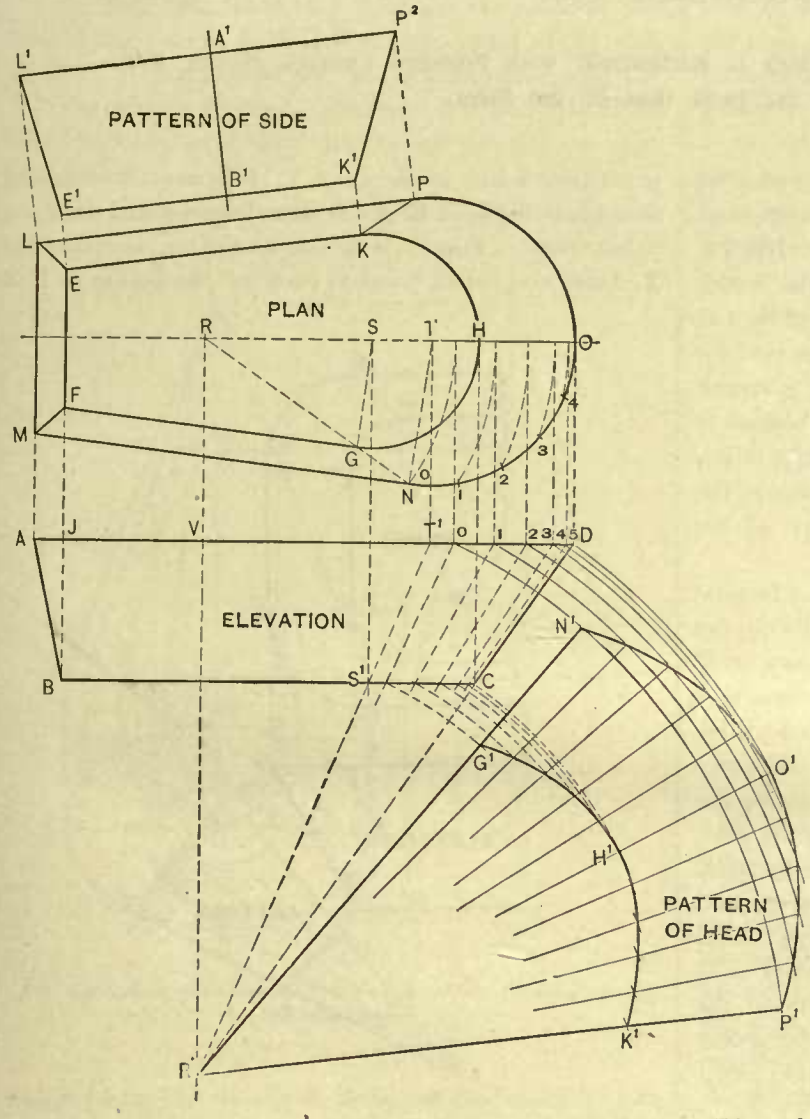


Fig. 544.—Plan, Elevation and Pattern of Flaring Tub with Tapering Sides and Semicircular Head.

N G H K is part of the envelope of a scalene cone. To find the apex of this cone, first drop lines from the points T and S vertically, cutting respectively the top and bottom lines of the elevation, as shown at T' and S'. A line connecting T' and S' will give the inclination of the axis of the cone in that view, which continue indefinitely in the direction of R' until it intersects the side C D continued, as shown at R'. Then R' is the apex of the cone. From R' draw R' R vertically, cutting the center line of the plan at R. Then R shows the position of the apex of the cone in the plan. As the pattern of the curved portion consists of two symmetrical halves when divided by the center line of the plan, divide the curve N O into any convenient number of equal spaces, as shown by the small figures. Lines drawn from each of these points to R would represent the bases of a series of right angled triangles whose common altitude is V R', and whose hypothenuses when drawn will represent the correct distances from the apex to the various points assumed in the base of the cone.

The simplest method, however, of measuring these bases is to place one foot of the compasses at the point R, and, bringing the pencil point successively to the points in N O, draw arcs cutting the center line, as shown between T and O. Now place the blade of the T-square parallel to R R' and drop lines from each of these points, cutting the line A D as shown. From the points obtained upon A D draw lines toward the apex R', cutting the bottom line of the tub B C. These lines drawn from the points in A D to R' will be the desired hypothenuses and may be used in connection with the spaces of the plan in developing the envelope of the scalene cone.

Therefore from R' as center, and radii corresponding to the distance from R' to the several points in T' D, describe a set of arcs indefinitely, as shown. Assume any point upon the arc 0, as N', as a starting point, from which draw a line to R'. With the dividers set to the space used in dividing the plan N O, place one foot at the point N' and swing the other foot around, cutting the arc 1. Repeat this operation, cutting the arc 2, and so continue to step from arc to arc until all the arcs have been reached, which will complete the outline of one-half the pattern. The operation of stepping from arc to arc can be continued, stepping back from arc 5 till arc 0 is reached at P', thus completing the top line of the pattern of the entire curved portion of the tub. From each of the points thus obtained draw lines toward the apex R', as shown. Place one foot of the compasses at R', and, bringing the pencil point successively to the points in

the line S' C previously obtained, cut radial lines of corresponding number in the pattern, as shown from G' to K'. Lines traced through the several points in the two outlines, as shown by G' H' K' and N' O' P', will complete the pattern of the conical part of the tub. The patterns of the sides and foot may be obtained as described in Problem 74 and as indicated in the upper part of the engraving.

PROBLEM 170.

The Pattern of a Flaring Article which is Rectangular with Rounded Corners, Having More Flare at the Ends than at the Sides.

In Fig. 545, A B C D E F represents the plan at the top of a portion of the flaring article, whose general shape is rectangular with rounded corners. G H I J K L represents the plan of the bottom of the same, showing that the flare at the ends, represented by I C or J D, is greater than that of the sides, represented by A G. The arc E D of the plan of the top is struck from O as center, while the arc J K of the bottom is struck from N. Since the top and bottom are parallel, as shown by P Q and P S of the side elevation, the corner J D E K is a portion of the envelope of the frustum of a scalene cone.

To find the apex of the cone, drop lines from O and N at right angles to P Q, cutting respectively the top and bottom lines in the side view, as shown at T and U, and draw T U and continue the same indefinitely in the direction of X. Also continue Q S until it intersects T U at the point X. Then X will be the apex of the cone. From X erect a line vertically, cutting the line D M of the plan at M; then M will show the position of the apex of the cone in plan. Divide the arc E D into any convenient number of equal spaces, and from the points thus obtained draw arcs from M as center, cutting O D, as shown. From the points in O D drop lines vertically, cutting T Q, the top line of the side, otherwise the base of the cone. From the points thus obtained in T Q draw lines toward the apex, cutting U S.

With one foot of the compasses set at X, bring the pencil point successively to the points in T Q and draw arcs indefinitely, as shown. From any convenient point upon the arc 0, as E', draw a line to X, forming one side of the pattern. Take between the points of the dividers a space equal to that used in stepping off the plan of cone E D, and, placing one foot at the point E', swing the other foot around, cutting the arc 1, from which intersection step to the next arc, and so continue until all the arcs have been reached at D', from which point draw a line to the apex X. Likewise from each of the points between E' and D' draw lines toward the apex indefinitely. Finally, with one foot of the compasses at X, bring the pencil point to each of the points in U S

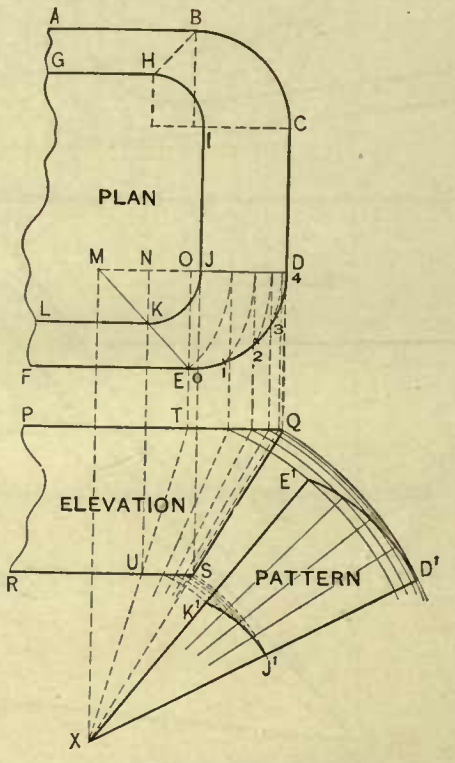


Fig. 545.—Plan, Elevation and Pattern of Rounded Corner for an Article whose Sides and Ends Flare Unequally.

and draw arcs, cutting radial lines of corresponding number in the pattern. Lines traced through the points between the points K' and J' and E' and D' will complete the pattern of the curved corner. The pattern for the plain sides can easily be obtained after the manner described in Problem 74 and added to that of the corner as may be found practicable.

PROBLEM 171.

The Pattern of a Flaring Article which Corresponds to the Frustum of a Cone whose Base is a True Ellipse.

In Fig. 546, let G H F E be the elevation of one side of the article, L M U R the elevation of an end, E' R' F' U' the plan of the article at the base, and T V S P the plan at the top. Produce E G and F H of the side elevation until they meet in the point I, the apex of the cone.

Divide one-quarter of the plan E' R' into any con-

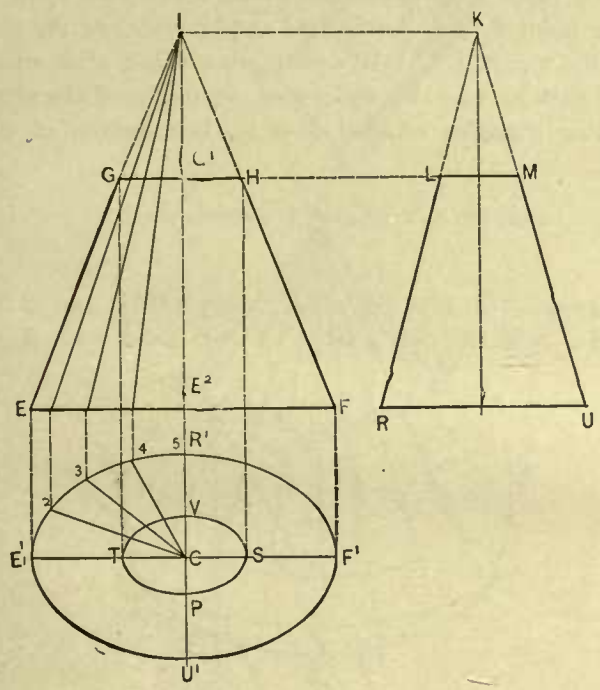


Fig. 546.—Plan, Side and End Elevations of the Frustum of an Elliptical Cone.

venient number of equal parts, as indicated by the small figures. From the points thus determined draw lines to the center C. These lines will form the bases of a series of right angled triangles whose common altitude is the hight of the cone, and whose hypothenuses when drawn will give the true distances from the apex to the several points assumed in the base of the cone. Therefore at any convenient place draw the straight line D A of Fig. 547, in length equal to I E². Make D B equal to I G'. From A and B of Fig. 547 draw perpendiculars to D A indefinitely, as shown by A O and B N. Take the distances C 5, C 4, C 3, etc., of the plan and set off corresponding distances from A on A O, as shown by A 5, A 4, A 3, etc. From these points in A O draw lines to D, cutting B N. These lines are also shown in the elevation, but are not necessary in that view in obtaining the pattern. From D as center describe arcs whose radii are equal to the lengths of the several lines just drawn from D to the points in A O.

From any convenient point in the first arc draw a

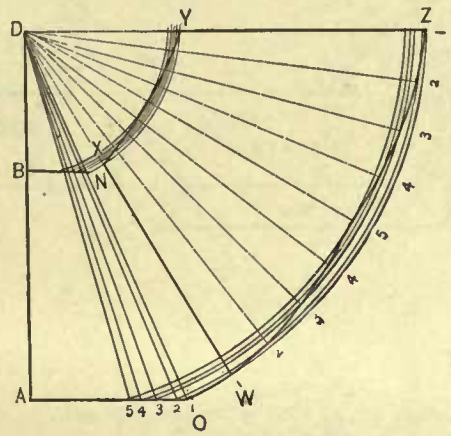


Fig. 547.—Diagram of Triangles and Pattern of Frustum Shown in Fig. 546.

straight line to D, as shown by W D. This will form one side of the pattern. From W, as a starting point, lay off the stretchout of the plan E' R' F', etc., using the same length of spaces as employed in dividing it, stepping from one arc to the next each time, as shown. A line traced through these points will be the outline of the base of the pattern, one-half of the entire envelope being shown in the pattern from W to Z.

From the points in W Z draw lines to D, which intersect by arcs drawn with D as center and starting from points of corresponding number in B N. A line traced through the points of intersection will form the upper line of the pattern, as shown. Then W X Y Z will constitute the pattern of one-half of the envelope, to which add a duplicate of itself for the complete pattern.

PROBLEM 172.

The Patterns for a Hip Bath.

In Fig. 548, let H A L N O be the elevation of the bath, of which D' G E' B' is a plan on the line D E. Let the half section A^2 M C' B^2 represent the flare which the bath is required to have through its sides on a line indicated by A B in elevation. By inspection of the elevation it will be seen that three patterns are required, which, for the sake of convenience, have been numbered in the various representations 1, 2 and 3.

Since the plan of piece No. 1 on the line D B,

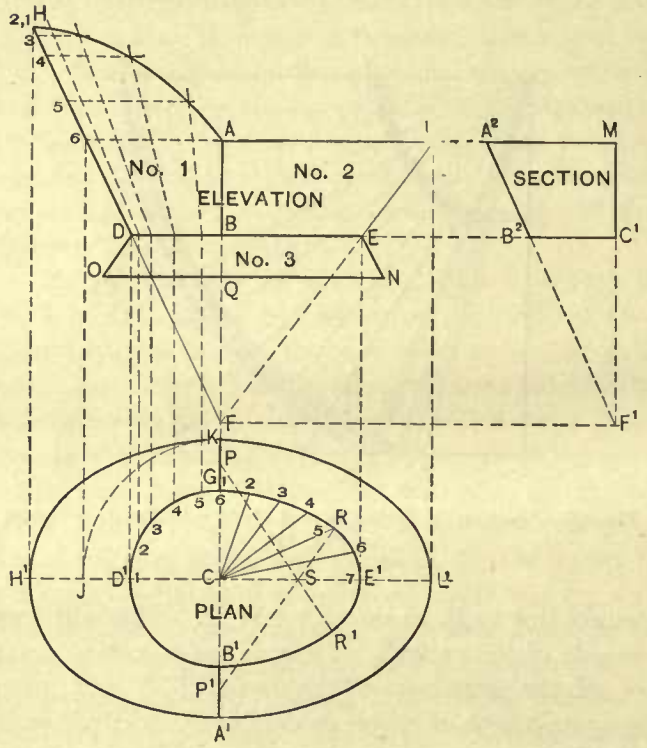


Fig. 548.—Plan, Elevation and Section of a Hip Bath.

which is at right angles to its axis A F, is a semicircle, as shown by G D' B', and since its flare at the side, as shown by C' B^2 A^2, is the same as at B D H, its pattern will be a portion of the envelope of a right cone. Patterns of this class have been treated in the previous section of this chapter—to which the reader is referred—where, in Problem 143, an exactly similar subject has been treated. The operation of obtaining this pattern is fully shown in Fig. 549, and, therefore, need not be here described.

Piece No. 2, as shown in Fig. 548, is so drawn as to form one-half of the frustum of an elliptical cone. As its section at A B (shown at the right) must necessarily be the same as that of piece No. 1, against which it fits, the point F is assumed as the apex of the elliptical cone, and consequently the flare at the foot, E L, is determined by a continuation of the line drawn from the apex through E. Should it be decided to have more flare at the foot than that shown by E L, the point L may be located at pleasure, and the plan of the top, K L' A^1, be drawn arbitrarily; after which its pattern may be developed by means of the alternating triangles alluded to in the introduction of this

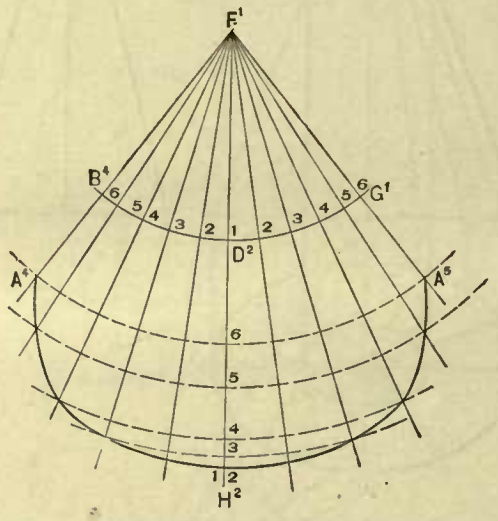


Fig. 549.—Pattern of Piece No. 1 of Hip Bath.

section (page 306), examples of which will be found further on in this section.

The plan G E' B', from which the dimensions of the pattern are to be determined, may be a true ellipse, or may be composed of arcs of circles, as shown, according to convenience. Divide one-half the plan G E' into any convenient number of equal spaces, as shown by the small figures, and from each point thus obtained draw lines to the center C. To avoid confusion of lines a separate diagram of triangles is constructed in Fig. 550, in which M C is the hight of the

tub or frustum and M F the hight of the cone. Draw M L and C E, each at right angles to M F. Upon C E set off from C the lengths of the several lines C 1, C 2, etc., of the plan. Through each of the points in C E draw lines from F, cutting the line M L. From F as center draw arcs indefinitely from each of the points in C E and also from the points in M L.

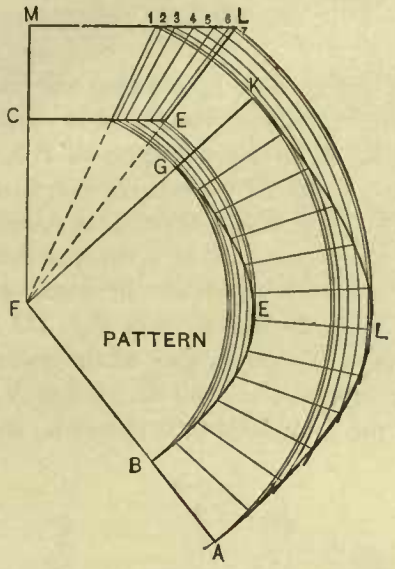


Fig. 550.—Pattern of Piece No. 2 of Hip Bath.

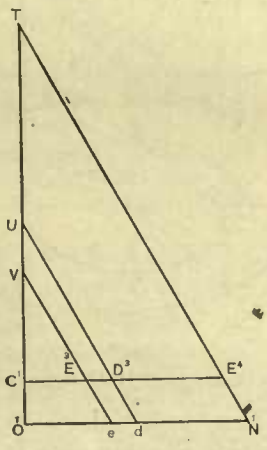


Fig. 551.—Diagram of Radii for Pattern of Foot.

Through any point upon arc 1 of the lower set, as G, draw a line from F and extend it till it cuts arc 1 of the upper set at K; then K G will be one side of the pattern. With the dividers set to the space used in dividing the plan G E', place one foot at the point G of the pattern and step to arc 2, and so continue stepping from one arc to the next till all are reached, as at E, and repeat the operation in the reverse order, finally reaching B and completing the lower line of the pattern. From each of the points in G E B draw lines radially from F, cutting arcs of corresponding

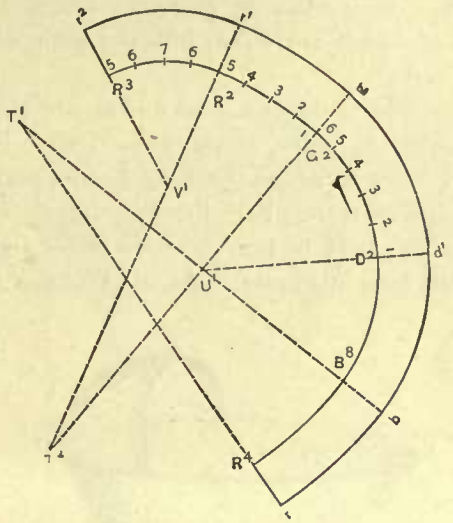


Fig. 552.—Pattern of Foot of Hip Bath.

number drawn from M L. Lines traced through these points of intersection will complete the upper line of the pattern. Then G E B A L K will be the required pattern of piece No. 2.

As the plan D' G E' B' has been drawn entirely from centers (C, P, S and P'), the pattern of piece No. 3 is exactly similar to that described in Problem 134 of the previous section of this chapter, to which the reader is referred. In Fig. 551 is shown a diagram for obtaining the radii taken from dimensions given in Fig. 548, while Fig. 552 shows the pattern described by means of the radii given in Fig. 551.

PROBLEM 173.

The Patterns for a Soapmaker's Float.

In Fig. 553 is shown a perspective view of a soapmaker's float. In general characteristics it is very similar to piece No. 2 of the hip bath treated in the preceding problem. It also resembles the bathtub in that its bottom is bulged or raised with the hammer, and is therefore not included in the field of accurate pattern cutting. The sides are to be considered as parts of two cones having elliptical bases, the short diameters of which are alike, but the long diameters of which vary.

In Fig. 554 is shown a plan and an inverted elevation of the flaring sides, showing in dotted lines the completed cones of which the sides form a part. Thus L D' M represents one-half the base of an elliptical cone of which L M is the short diameter and D' K' one-half the long diameter. As all sections of a cir-

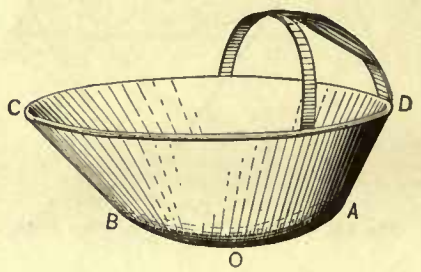


Fig. 553.—Perspective View of Soapmaker's Float.

cular cone taken parallel to its base are perfect circles, so all sections of an elliptical cone parallel to its base must be ellipses of like proportions with the base. Therefore the plan of the upper base of the frustum A' P must be so drawn that a straight line from A' to P will be parallel to a straight line joining D' and L.

For the pattern of the portion shown by D A E F of the elevation, first produce the line F E of the elevation in the direction of K indefinitely. In like manner produce D A of the elevation until it reaches F E produced in the point K. Then D K F may be regarded as the elevation of a half cone, of which that part of the vessel is a portion, and K F its perpendicular hight. Next, divide one-half the plan L D' M into any number of equal parts, as shown by the small figures 1, 2, 3, etc. Construct the diagram of triangles, shown in Fig. 555, by drawing the line D K' of indefinite length, and the line K' K at right angles to it, making K' K in length equal to F K, Fig. 554. Establish the point K² by making the distance K' K² equal to E F of Fig. 554. Draw K² A parallel to K' D. From each of the points 2, 3, 4, etc., of the plan draw lines to the center K', and set off distances equal to these lines upon the line K' D of Fig. 555, measuring from K' toward D. From each of the points thus obtained draw lines to the point K, cutting A K². With one foot of the compasses in the point K, and the other

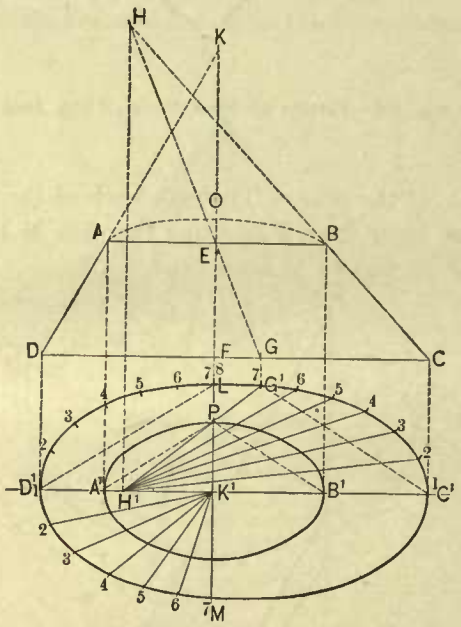


Fig. 554.—Plan and Inverted Elevation of Soapmaker's Float.

brought successively to the points 1, 2, 3, etc., in the line D K' and also to the points in the line A K², describe arcs indefinitely.

Take in the dividers a space equal to the divisions in D' L of Fig. 554, and, commencing at the point *a* in arc 7 (Fig. 555), step to arc 6 and thence to arc 5, and thus continue stepping from one arc to the next until the entire stretchout of the half plan has been laid off, as shown in Fig. 555. From each of the points thus obtained in *a d* draw lines to K, cutting arcs of corresponding number drawn from A K². Then

a line traced through the several points of intersection thus obtained, as shown by *b c* and *a d*, will be the boundary lines of the pattern.

The pattern for the other end of the article is to be, in the main, developed in the same manner as above described. One additional condition, however, exists in connection with this piece, viz.: To determine the dimensions of the cone of which this piece (E B C F, Fig. 554) is a part, since the flare at B C is much greater than A D, while the flare of both pieces at the side is the same as shown by P L of the plan. The quarter ellipse P B' of the plan being given, and also the point C', it becomes necessary to draw from C' a quarter ellipse which shall be of like proportions with

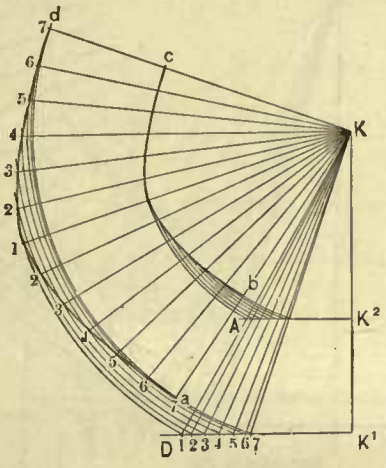


Fig. 555.—Diagram of Triangles and Pattern of Piece L D' M of Fig. 554.

P B', which, as remarked above, is a necessary condition, both being horizontal sections of the same cone. To do this proceed as follows: Connect the points P and B' by means of a straight line. From the point C' draw a line parallel to P B', and produce it until it cuts the line L G', which is a straight line drawn at right angles to L M. Then G' becomes a point in the lower base of the cone corresponding to the point P in the upper base. Draw the line G' P, and continue it until it intersects the long diameter in H'. Drop the point G' vertical from the plan on to the base line D C of the elevation, as indicated by the point G. Draw a line through the points G and E, which produce indefinitely in the direction of H. In like manner produce the side C B of the cone until it intersects G E produced in the point H. Then it will be found that the point H of the elevation and the point H' of the plan coincide, as indicated by the line H H'. H G of the elevation thus represents the axis and H C one side of the cone of which the piece E B C G is a part, from which it will be seen that this cone is at once elliptical and scalene. The operation of developing the pattern from this stage forward is the same as in the previous case, all as clearly shown in Fig. 556, save only in the addition of the triangular piece indicated by G E F of the elevation. After completing the other

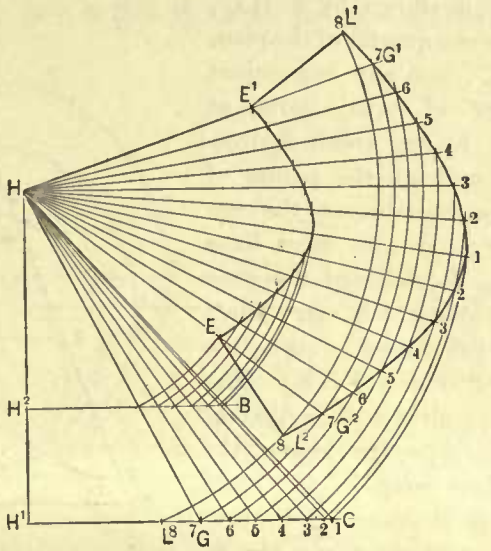


Fig. 556.—Diagram of Triangles and Pattern of Piece L C' M of Fig. 554.

portions of the pattern, this triangular piece is added as follows: The distance H' L in Fig. 556 is to be set off on the line H' C in the same manner as the distances to the other points—*i.e.*, H' L is equal to H' L of Fig. 554. Then L is to be treated in the same manner as the other points, an arc being struck from it, as indicated in the engraving, by which to determine the corresponding point L² in the outline of the pattern. L² G² is made equal to L G' of the plan, Fig. 554. From L² draw a line to E. Then E L² G² will be the pattern of the triangular piece indicated in Fig. 554 by E F G. It is to be added upon the opposite end of the pattern in like manner, as indicated by E' G' L'.

PROBLEM 174.

The Envelope of a Frustum of an Elliptical Cone Having an Irregular Base.

The form E F K L J shown in Fig. 557, the lower line of which is an irregular section through an elliptical cone, is introduced here, not as representing any particular article or class of forms, but because it embodies a principle somewhat different from other sections of cones previously given, which may be useful to the pattern cutter.

B A C is the side elevation of a cone having an elliptical base, one-half of which is shown by B¹ H C¹. Divide one quarter of the plan, as H C¹, into any convenient number of equal parts, as shown by the small figures. From each of the points of division draw lines to the center D², and also erect lines cutting the base of the cone B C, from which carry them toward the apex, cutting the lines E F and J L K. The first operation will be that of obtaining the envelope of the complete cone in the same manner as described in previous problems.

Construct a diagram of triangles, as shown at the right, in which A¹ D¹ is equal in hight to A D, and at right angles to G¹ W and D¹ V, extensions respectively of E F and B C. Upon D¹ V, measuring from D¹, set off the distances from D² to the several points in H C¹, as shown. From each of the points thus obtained draw lines toward A¹, cutting G¹ W. Also from each of these points, with A¹ as center, describe arcs indefinitely. Take between the points of the dividers a space equal to that used in dividing the plan H C¹, and placing one foot upon the arc drawn from point 1 in the line D¹ V, step to arc 2, thence to arc 3 and so continue till one quarter of the stretchout is completed at 7, and, if desirable, continue the operation, taking the arcs in reverse order, thus completing the outline of one-half the envelope of the cone, as shown in the engraving. From each of the points in this outline or stretchout draw measuring lines toward the center A¹. Place one point of the compasses at point A¹, and, bringing the pencil point successively to the several points of intersection on the line G¹ W, cut measuring lines of corresponding number, as shown from G¹ to G². Place the T-square parallel to the base B C, and, bringing it successively to the several points of intersection previously obtained in the curved line L K, cut lines of corresponding number drawn from the points in D¹ V to A¹, as shown from X to Y. Finally, with one foot of the compasses at A¹, bring the pencil point to each of the points of intersection last obtained and cut corresponding measuring lines in the pattern. Then lines traced through the points of intersection, as shown from L¹ to L² and from G¹ to G², will complete the pattern of one-half the frustum E F K L J.

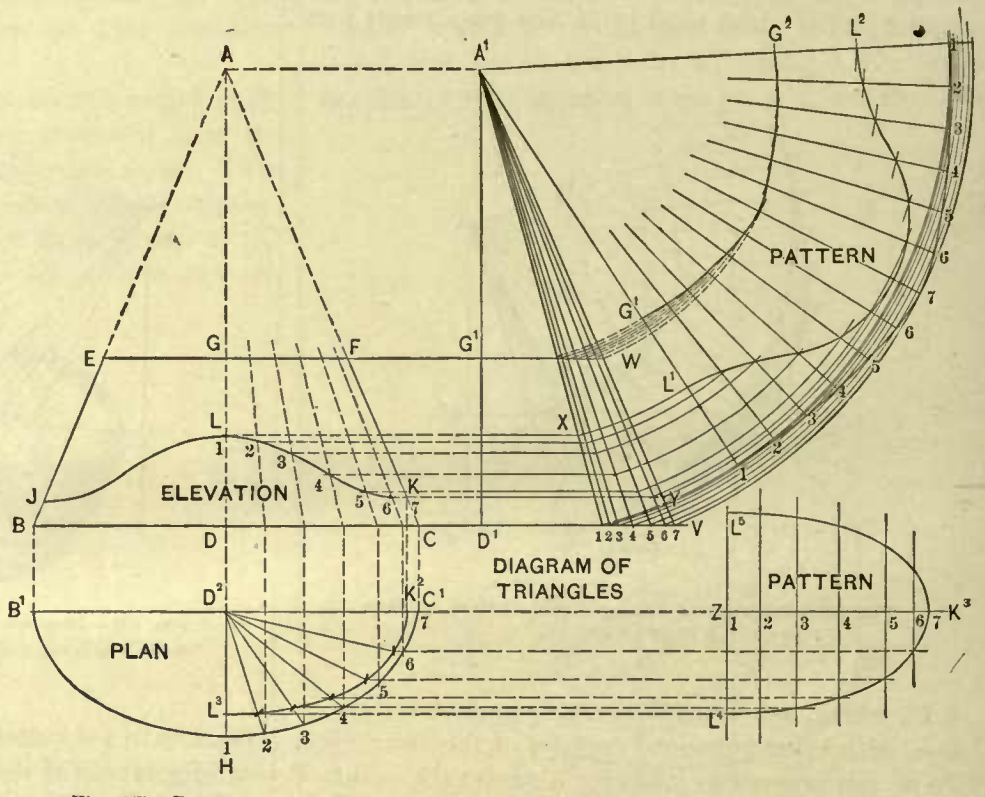


Fig. 557.—Patterns for the Frustum of an Elliptical Cone Having an Irregular Base.

Should it be desirable to cut a pattern to fill the end J L K of the frustum, as for a bottom in the same, it will first be necessary to obtain a correct plan

of the line J K L. To accomplish this, set off on the lines D^2 7, D^2 6, etc., of the plan the lengths of the several lines of corresponding number drawn from the line G^1 D^1 to the intersections between X and Y, thus obtaining the desired line L^3 K^3. Extend the center line B^1 C^1 of the plan, as shown at the right, upon which lay off a stretchout of the line L K, taking each of the spaces separately as they occur, all as shown by Z K^3, through which draw measuring lines at right angles. Place the T-square parallel to B^1 C^1, and, bringing it to the several points in the line L^3 K^3, cut corresponding measuring lines. Then a line traced through the points of intersection, as shown by L^4 K^4, will be the pattern of one-quarter of the desired piece, which may be duplicated as necessary for a half or for the entire pattern in one piece.

PROBLEM 175.

The Patterns of the Frustum of a Scalene Cone Intersected Obliquely by a Cylinder, their Axes Not Lying in the Same Plane.

In Fig. 558, let A B C D represent the frustum of an oblique cone, and T S R V U the cylinder that joins the same at the angle indicated. The view here given of the frustum is that of its vertical side, so that A D and B C are the outlines of the slanting sides. In Fig. 559 E F G H shows the plan of the frustum at its base and K I J G the plan of the top, from which the side elevation is projected at the left, D C

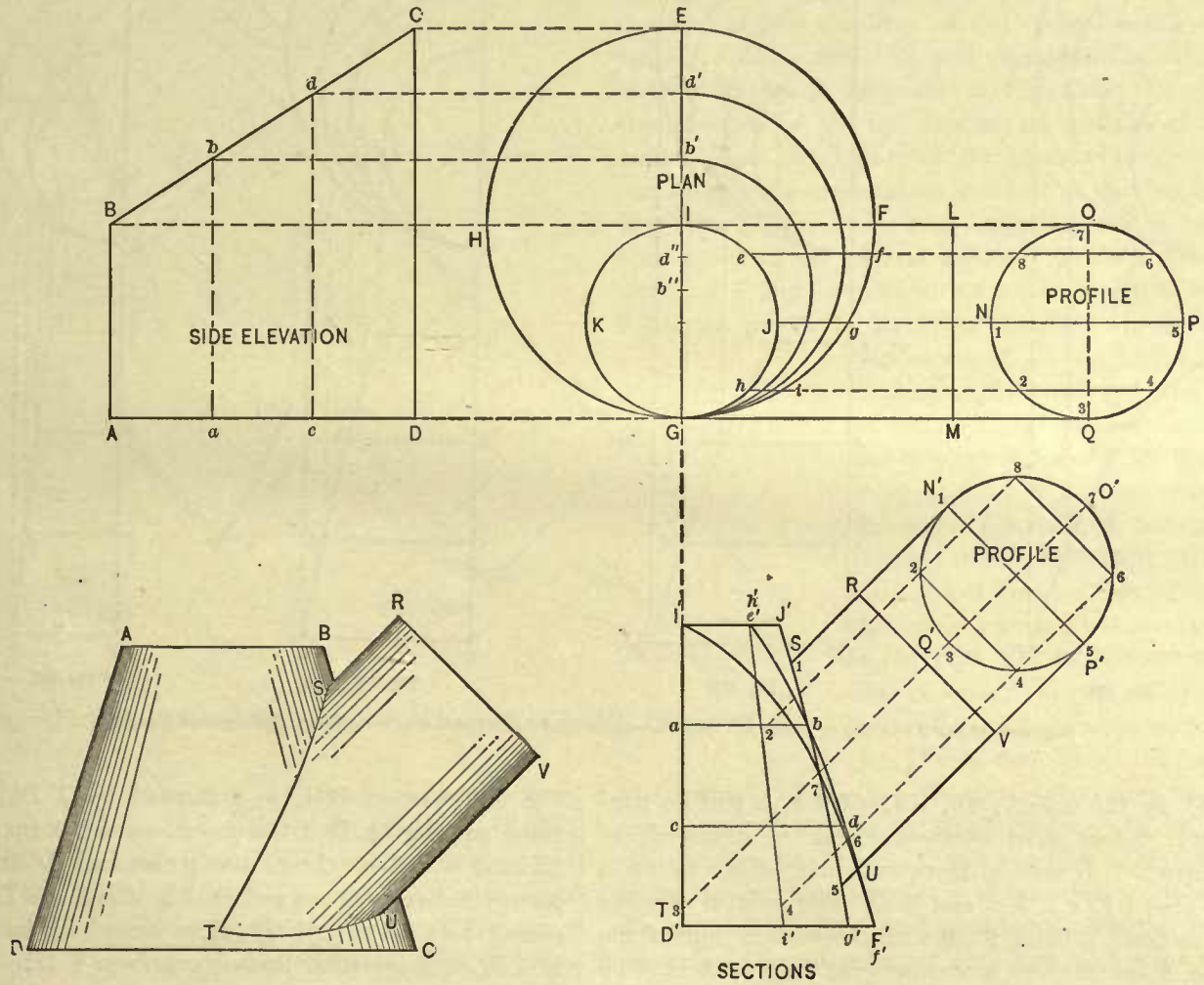


Fig. 558.—Front Elevation of the Frustum of a Scalene Cone Intersected Obliquely by a Cylinder.

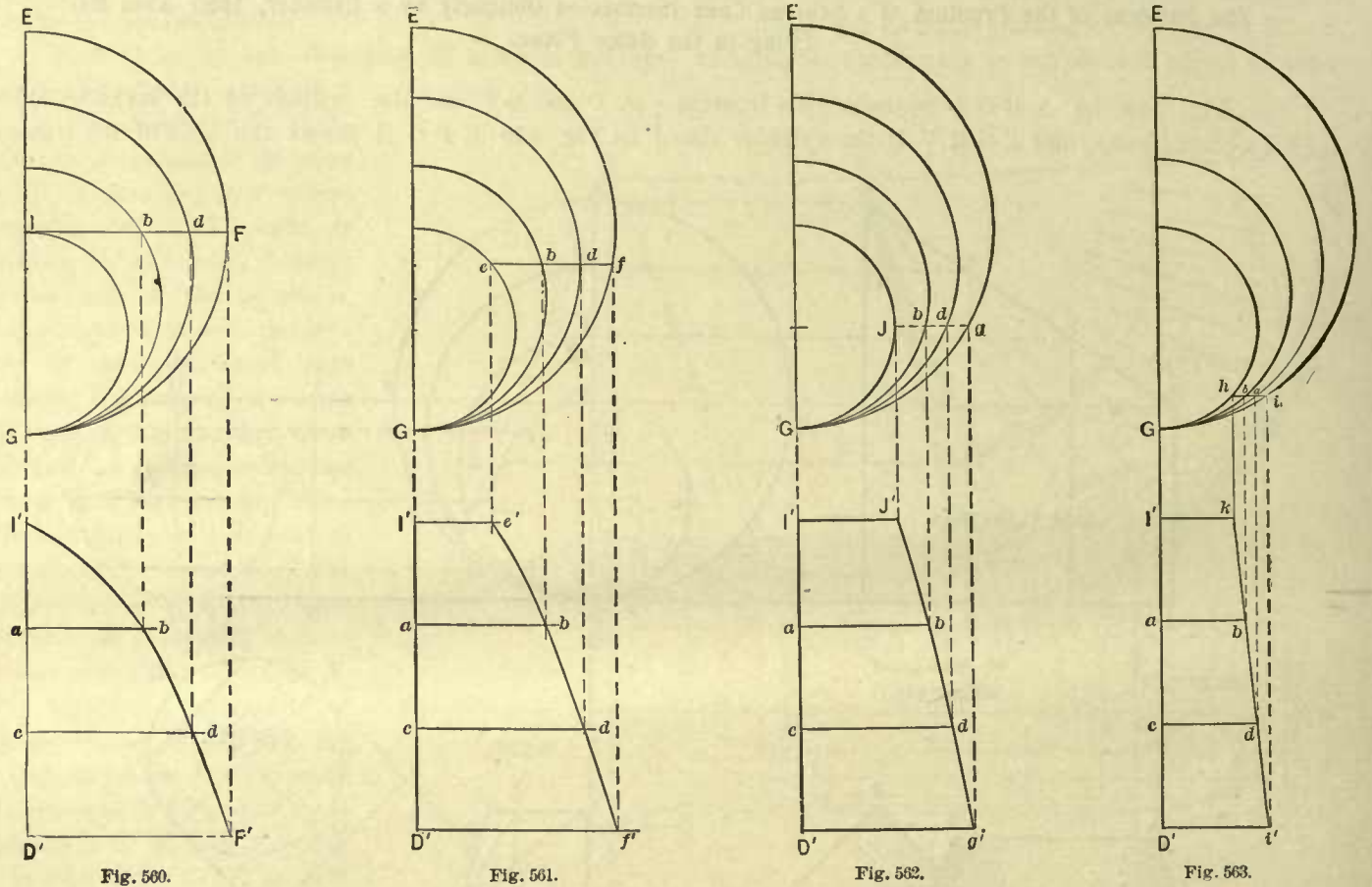
Fig. 559.—Elevation, Plan and Sections of the Frustum of a Scalene Cone Intersected Obliquely by a Cylinder.

being the base and A D the vertical side. The intersecting cylinder is indicated by F L M G, and its profile by N O P Q. The diameter of cylinder is the same as that of top of frustum.

Divide the profile N O P Q into any convenient number of equal parts, and from the points thus obtained carry lines parallel with G M, cutting I J G and F G of plan, as shown. As the points in the profile of the cylinder lie in four vertical planes, indicated by the lines 7, 8 6, 1 5, and 2 4, it will be necessary, before their intersection can be obtained, to construct four vertical sections through the cone upon the lines I F, *e f*, J *g*, and *h i*. The point 3 requires no section; it being flush with the vertical side of the cone, must intersect somewhere on the line A D. To obtain the desired sections divide A D of elevation into any convenient number of equal parts, and from the points thus obtained erect lines parallel to the base D C, cutting B C. From the points in B C carry lines parallel with A G, cutting the center line E G, as shown. With *b''* and *d''* as centers, strike the arcs G *b'* and G *d'*, thus forming sections of the cone in plan corresponding with *a b* and *c d* of elevation. The four vertical sections above referred to are shown below the plan by I' F', *e' f'*, J' *g'* and *h' i'*. To avoid a confusion of lines, the method of obtaining the shapes is shown separately in Figs. 560 to 563, in which the reference letters are the same as in Fig. 559.

To obtain the shape of section on line I F in Fig. 560, extend E G, as indicated by I' D', which make equal to A D of the elevation, with its points of division *a* and *c*. From the points in I' D' erect the perpendiculars *a b*, *c d* and D' F'. With the T square placed parallel with I' D', drop lines from the points in I F, cutting similar lines drawn from I' D'. A line traced through the points of intersection, as shown by I' F', will give the required shape. The sections shown in Figs. 561, 562 and 563 are obtained in a similar manner.

Having obtained these sections of the cone by the



Sections of the Frustum of Scalene Cone Corresponding to Divisions in Profile of Cylinder in Fig. 559.

above method, arrange them as shown below the plan in Fig. 559. An inspection of the plan and profile will show that a line drawn from O of profile will cut section I F, line 8 6 of profile will cut section *e f*, line N P of profile will cut section J *g*, line 2 4 will cut section *h i*, and a line from Q of profile will cut the vertical side represented by G.

In connection with the sections in Fig. 559 draw an elevation of cylinder, as shown by S R V U, opposite the end of which draw a profile, as indicated by

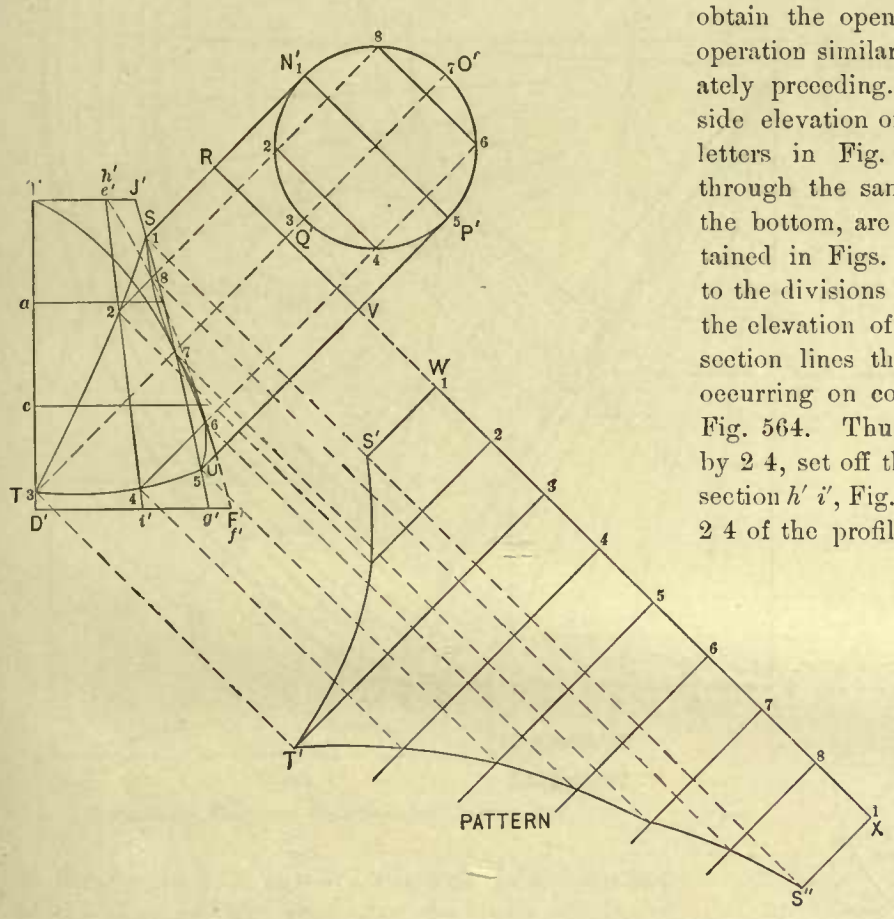


Fig. 564.—Method of Obtaining Pattern of Cylinder Shown in Figs. 558 and 559.

N′ Q′ P′ O′, commencing the divisions at the point N′. From the several points in the profile N′ O′ P′ Q′ carry lines parallel with U V against the several profiles I′ F′, *e′ f′*, J′ *g′* and *h′ i′* as described above and as indicated by the small figures 1 to 8. A line traced through these points of intersection will give the miter line. A duplicate of this part of Fig. 559 is presented in Fig. 564 for the purpose of avoiding a confusion of lines. The miter line drawn through the intersecting lines is indicated by S T U.

Having now the profile of the cylinder and the miter line, all as shown, the pattern of the cylinder is obtained in accordance with the principles given in numerous examples in Section 1 of this Chapter, and as clearly shown in Fig. 564.

The method of obtaining the envelope of the frustum, and the opening in the side of the same to fit against the end of the cylinder just obtained, is shown in Fig. 565. The simple envelope of the frustum is obtained exactly as described in Problem 167, as will be seen by a comparison of Figs. 565 and 541. To obtain the opening in its side, however, involves an operation similar to that given in the problem immediately preceding. A B C D of Fig. 565 represents a side elevation of the frustum, as shown by the same letters in Fig. 559, and the vertical lines drawn through the same, designated by the small figures at the bottom, are the lines of the vertical sections obtained in Figs. 560–563, and correspond in numbers to the divisions in the profile in Fig. 559. To obtain the elevation of the opening, set off on each of these section lines the hights of the points of intersection occurring on corresponding sections as they appear in Fig. 564. Thus upon line designated at the bottom by 2 4, set off the vertical hights of points 2 and 4 on section *h′ i′*, Fig. 564, which section corresponds to line 2 4 of the profile, as shown in Fig. 559. In the same manner set off on line 1 5 the vertical hights of the points 1 and 5 on section J′ *g′*. Obtain also points 8 and 6 from section *e′ f′* and point 7 from section I′ F′, all as shown by the small figures. A line traced through these points will give the elevation of the opening. The outline of the opening has been shown in the plan, but its development is not necessary to the subsequent work of obtaining the pattern.

Divide the plan of the base of the frustum G F E into any convenient number of equal spaces, as indicated by the small letters. As an accurate elevation of the opening has now been obtained, this operation can be conducted without reference to any of the points previously used in obtaining the line of the opening. Therefore letters have been used in the divisions of G F E instead of figures so that no confusion may arise. From each of these points of division draw lines to G, which represents the plan of the apex of the cone. Also from so many of these points from which lines will cut the line of the opening, as *a* to *f*, erect

lines vertically, cutting the base line D C, as shown by corresponding letters. From these points draw lines toward the apex of the cone X, cutting the line of the opening in the elevation, as shown but not lettered.

Proceed now to construct the diagram of triangles shown at the right, in which X¹ D¹ is equal to and parallel with X D, and in which A¹ B¹ and D¹ C¹ are drawn in continuation of A B and D C, as shown.

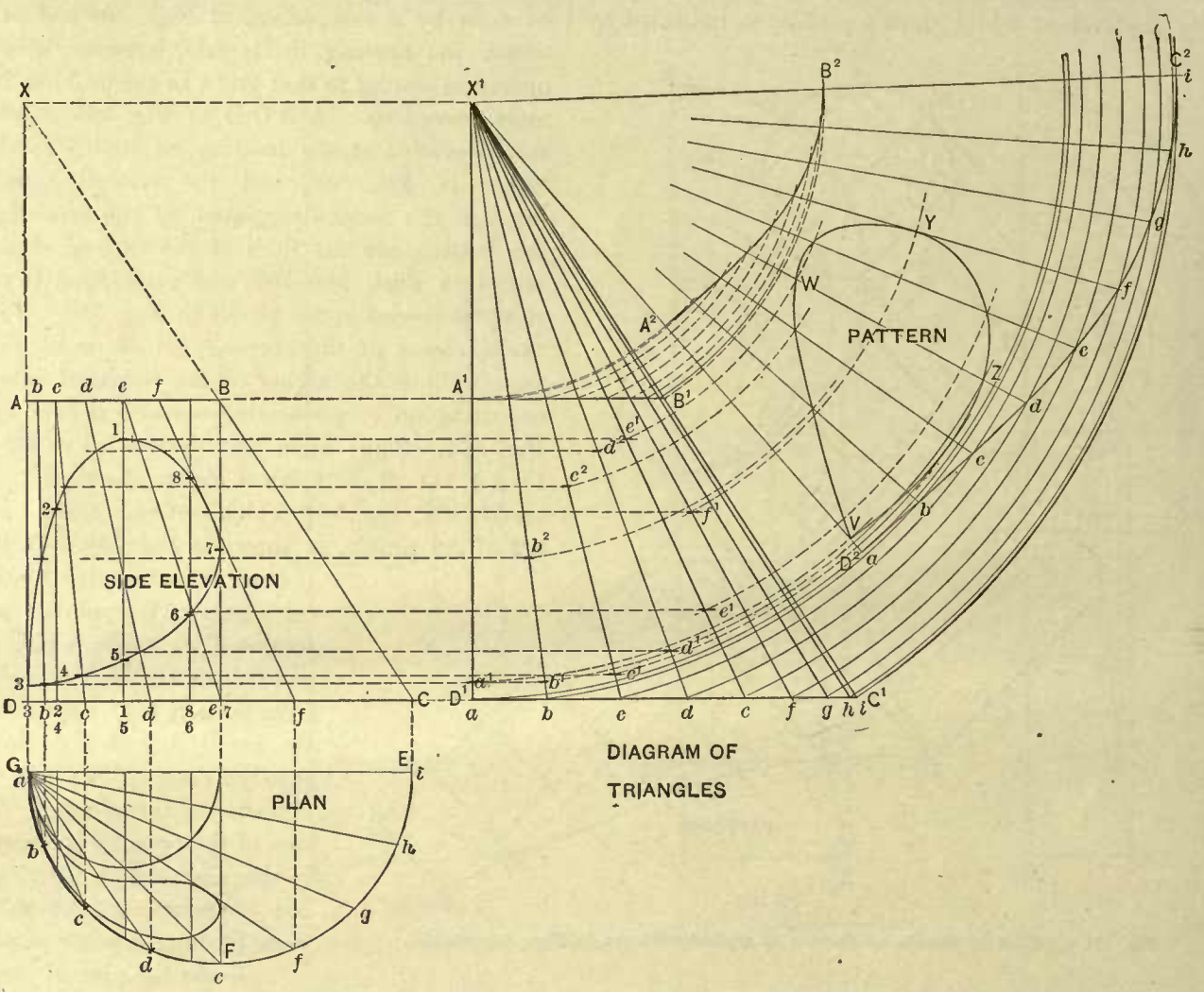


Fig. 565.—Method of Obtaining Opening in Side of Cone to Fit End of Cylinder.

Upon D¹ C¹, measuring from D¹, set off the several lengths G *b*, G *c*, etc., of the plan, as shown by corresponding letters, and from the points thus obtained draw lines to X¹, cutting the line A¹ B¹. From X¹ as center draw arcs indefinitely from each of the points in D¹ C¹. From any convenient point upon arc *a*, as D², draw a line to X¹, which will form one side of the pattern of the desired envelope. Take between the points of the dividers a space equal to that used in dividing the plan G F E, and, placing one foot of the dividers at D², step to arc *b*, thence to arc *c*, etc., till arc *i* is reached at C². A line traced through these points will give the lower outline of the half of the envelope of the frustum which is pierced by the cylinder. From each of these points also draw lines toward X¹, which intersect by arcs of corresponding number drawn with X¹ as center from the line A¹ B¹, thus obtaining the upper line of the envelope.

From each of the points where the lines *b b*, *c c*, *d d*, etc., of the elevation cross the line of the opening project lines horizontally, cutting hypothenuses of corresponding letter in the diagram of triangles, all as shown by a^1, b^1 b^2, c^1 c^2, etc. With one foot of the compasses at X¹, bring the pencil point successively to the points a^1, b^1, b^2, etc., and draw arcs cutting radial lines in the pattern of corresponding letter. Then a line traced through the points thus obtained will be the required shape of the opening in the pattern.

PROBLEM 176.

The Pattern for a Chimney Top.

In Fig. 566 are shown the side and end elevations and the plan of a chimney top. A B C D of the plan represents the size of the article at the bottom to fit the chimney, and E F G H is the size of the opening

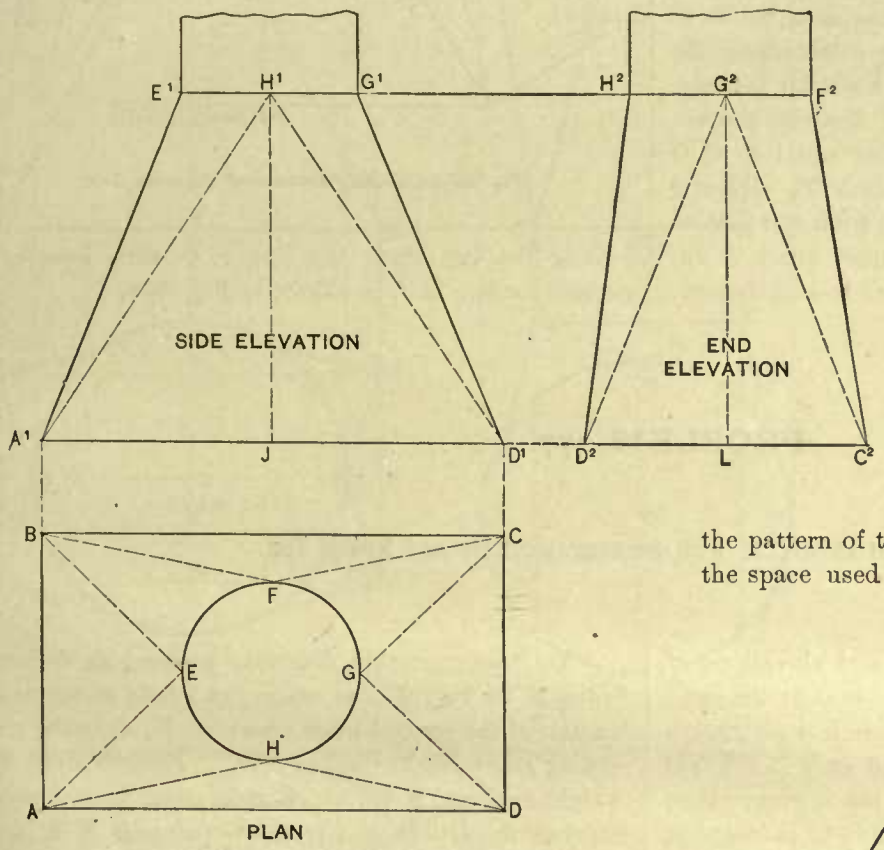


Fig. 566.—Plan and Elevations of Chimney Top.

in the top to fit a pipe or extension. An inspection of the drawings will show that the article consists of two flat triangular sides, of which A H D is the plan and A¹ H¹ D¹ the elevation, two similar triangles, D G C, forming the ends, and four corner pieces, of which F C G is a plan, which are portions of an oblique cone. Further inspection of the plan will also show that the entire article consists of four symmetrical quarters, therefore in Fig. 567 is shown a quarter plan of the same in which corresponding points are lettered the same as in Fig. 566, from which the pattern for one-quarter of the article is obtained.

The quarter circle F G is the quarter plan of an oblique cone, of which C is the apex; therefore divide F G into any convenient number of equal parts, and from the points thus obtained draw lines to C. The next step is to construct a diagram of triangles of which the lines just drawn are the bases and of which the hight of the article is the altitude. Assuming O C as the base line of this diagram, place one foot of the compasses at C, and, bringing the pencil point to the various points in F G, strike arcs cutting O C, as shown. At right angles to O C erect C Q, equal in hight to J H¹ of Fig. 566, and from Q draw lines to the several points in O C. These hypothenuses will then represent the true distances from C to the points in F G. From Q as center, and radii equal to the several hypothenuses, strike arcs indefinitely, as shown to the left. From any convenient point on arc 0, as G¹, draw a line to Q, which will form one side of the pattern of the rounded corner. Set the dividers to the space used in stepping off the arc F G, and, com-

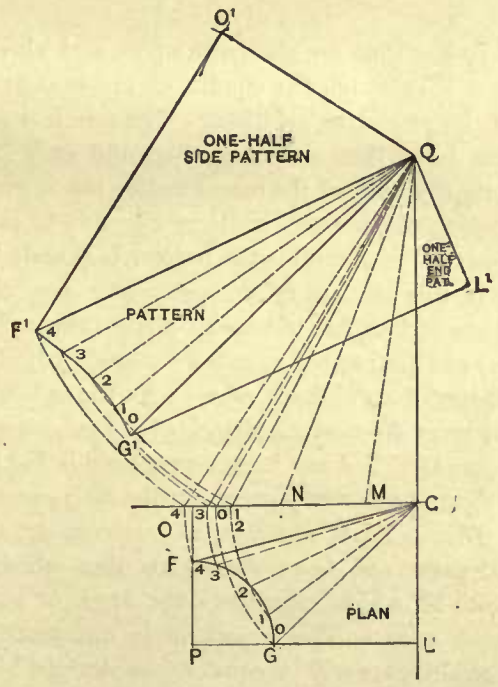


Fig. 567.—One-Quarter Plan and Pattern of Chimney Top.

mencing at the point G¹, step to arc 1 and from that point to arc 2 and so on, reaching the last arc in the

point F'. Trace a line through these points, as shown from F' to G', and draw F' Q, which will complete the pattern of the corner piece.

From C set off on O C the distances O F and L G, as shown by M and N. Draw lines from these points to Q, then M Q and N Q will represent the true distances shown by O F and G L of the plan or J H' and L G² of the elevations in Fig. 566.

With Q as center, and C L as radius, describe an arc, L', and from G' as center, with radius equal to N Q, intersect the arc, as shown, thus establishing the point L'. Draw G' L' and L' Q. In a similar manner, with F' as center, and Q M as radius, describe the arc O', and from Q as center, with a radius equal to C O of the plan, intersect the arc at the point O'. Draw Q O' and O' F'; then F' O' Q L' G' will form the pattern for one complete quarter of the chimney top. A duplicate of this pattern may be added to it if desired, joining the two upon the line F' O, thus forming a pattern for one half, as shown in Fig. 568.

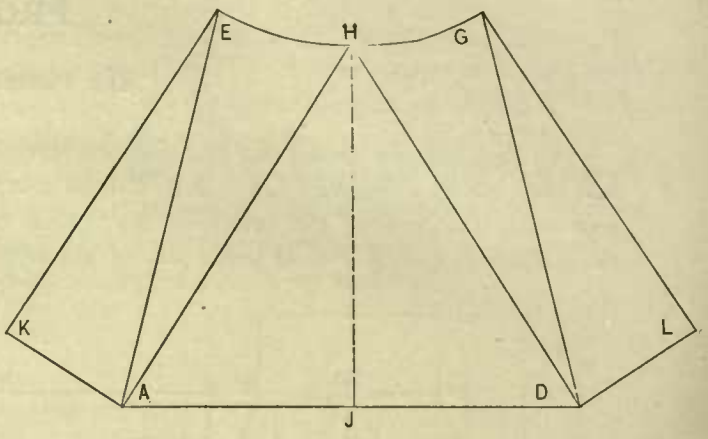


Fig. 568.—One-Half Pattern of Chimney Top.

PROBLEM 177.

The Pattern of an Article with Rectangular Base and Round Top.

In Fig. 569 are shown the plan and elevations of an article in which the conditions are exactly the same as in the preceding problem. The article here shown differs from that shown in Fig. 566 only in the fact that the diameter of the round end or top is greater than the width of the base, while in Fig. 566 it is less, but the method of obtaining the pattern is exactly the same.

In this case, as in the preceding one, the article consists of four flat triangular pieces (two ends and two sides) and four equal rounded corners, each of which is a quarter of an oblique cone. As the entire envelope consists of four symmetrical quarters, one-quarter of the plan O P N J has been reproduced in Fig. 570 from which to obtain the patterns in the simplest manner.

Divide J I of plan into any convenient number of equal parts, and from the points thus obtained draw lines to N, which represents the apex of an inverted oblique cone. The object is to construct triangles whose altitudes will be equal to the straight hight of the article, and whose bases will be equal to the length of lines in I J N of plan, and whose hypothenuses will give the distance from points in I J of top to N in the base.

To construct this diagram, proceed as follows: From N of Fig. 570 as center, and radii equal to the lengths of the several lines drawn to N, describe arcs, cutting any straight line, as N W. From N draw N *n* at right angles to N W, which make equal to the straight hight of the article, and from the points in N W draw lines to *n*. With *n* as center, and the distances from N to points in N W as radii, strike arcs as shown. From any point, as *i*, on arc 1, draw a line to *n*. Set the dividers to the space used in stepping off I J of plan, and, commencing at *i*, step from arc to arc, as indicated by the small figures, reaching the last in the point 7 or *j*. Draw *j n*, thus completing the pattern for part of article indicated in plan by I N J. From N on N W set off the distances Q J and I P, as shown by the points *q'* and *t'*. Then *n q'* and *n t'* will represent respectively the altitudes of the flat triangular pieces forming the sides and the ends of the article. With N Q of plan as radius, and *n* of pattern as center, strike a small arc (*q*), which intersect with one struck from *j* of pattern as center, and *n q'* of diagram as radius, thus establishing the point *q* of pattern. Draw *n q* and *q j*.

With P N of plan as radius, and n of pattern as center, strike a small arc, which intersect with one struck from i of pattern as center, and $n\ t'$ of the diagram as radius, thus establishing point p of pattern. Draw $i\ p$ and $p\ n$, as shown, thus completing the quarter pattern.

In Fig. 571 $i\ p\ q\ j$ is a duplicate of the pattern indicated by the same letters in Fig. 570. Below this the pattern is duplicated once, and above twice, each alternate pattern being reversed, thus completing the entire pattern in one piece.

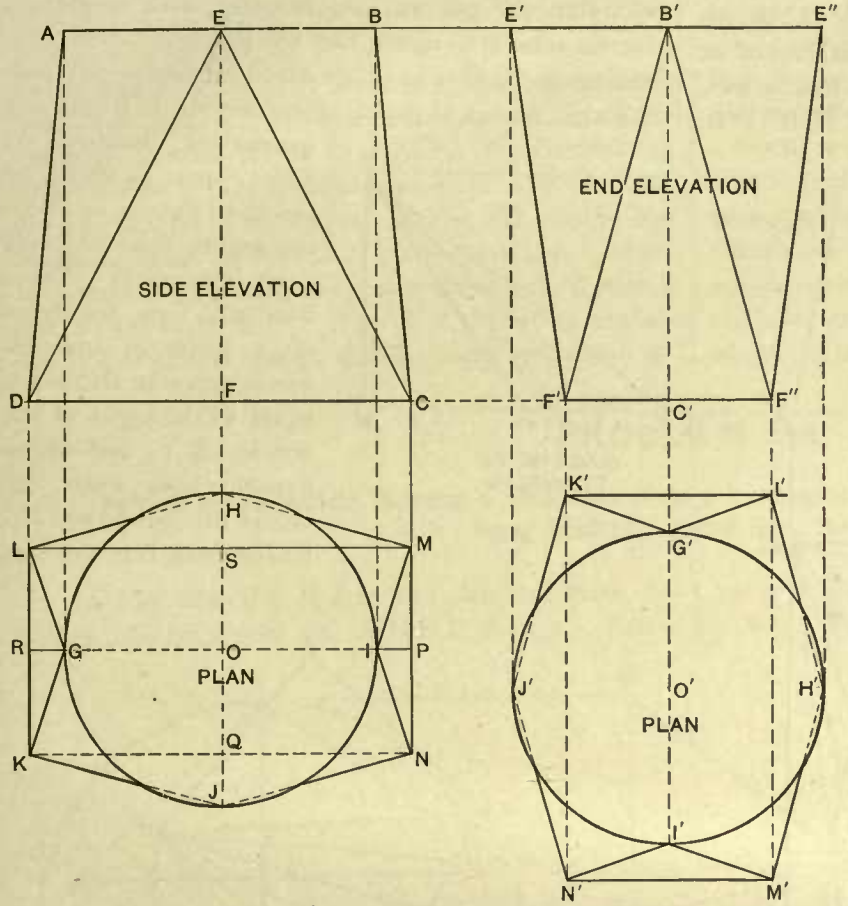


Fig. 569.—Plan and Elevations of an Article with Rectangular Base and Round Top.

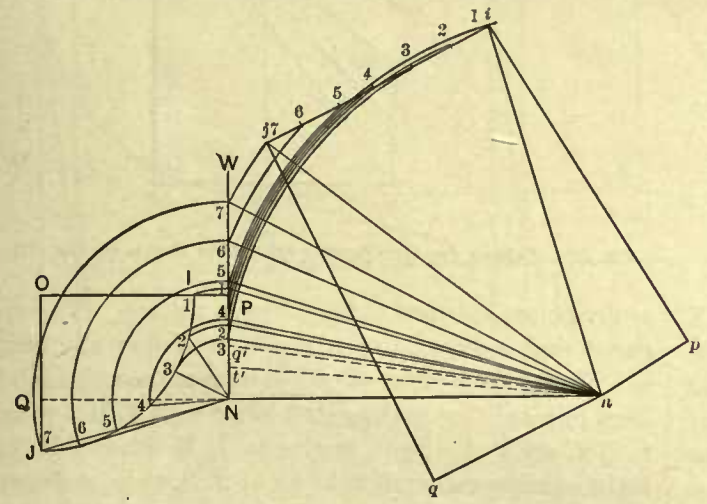


Fig. 570.—One-Quarter Plan and Pattern of Article Shown in Fig. 569.

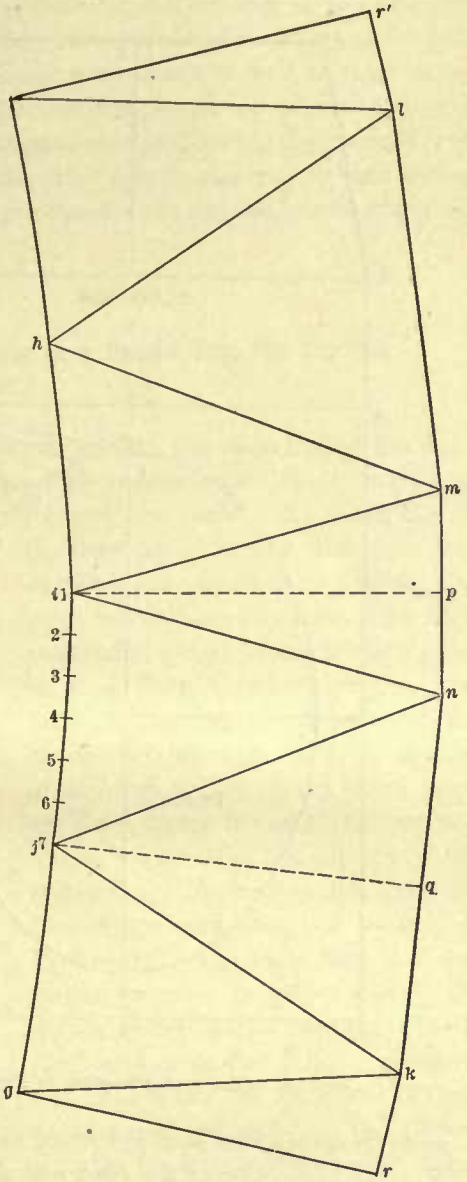


Fig. 571.—The Entire Pattern of Article shown in Fig. 569 in One Piece.

PROBLEM 178.

Pattern for an Article Forming a Transition from a Rectangular Base to an Elliptical Top.

In Fig. 572, A B B′ A′ of the plan shows the rectangular base and C E D F the elliptical top of an article, the sides of which are required to form a transition between the two outlines. A″ C′ D′ B″ is an end elevation of the same, showing its vertical hight X Y. An inspection of the plan will show that the article consists of four symmetrical quarters, and that that part of either quarter lying between the curved outline of the top and the extreme angle of the base, as the part E D B, is a portion of the envelope of an oblique elliptical cone, of which E D is the base and B the apex.

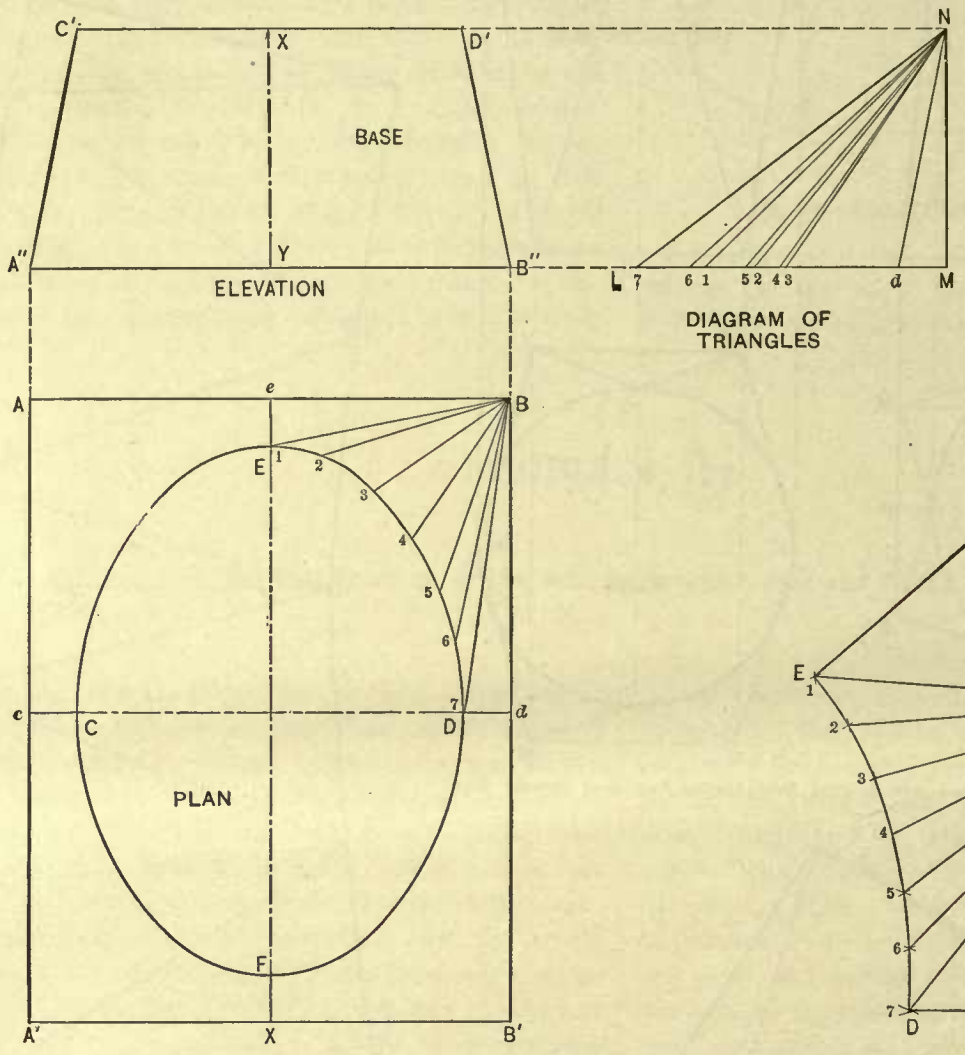


Fig. 572.—Plan and Elevation of Transition Piece.

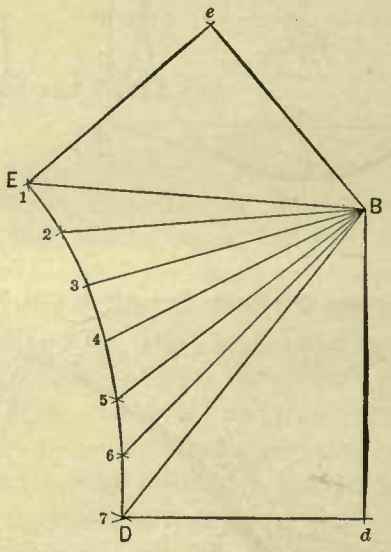


Fig. 573.—Pattern for One-Quarter of Article Shown in Fig. 572.

The conditions here given are exactly the same as in the two preceding problems; a different method of obtaining the pattern has, however, been employed, not because it is better but for the sake of variety, leaving the reader to judge which method is the more available in any given case. Divide E D into any convenient number of equal spaces, as shown by the small figures, and from the points thus obtained draw lines to B. These lines will form the bases of a series of triangles whose common altitude is equal to the hight of the article, X Y, and whose hypothenuses when obtained will be the real distances from B in the base to the points assumed in the curve of the top. To construct such a diagram of triangles, first draw any line, as L M, and from M lay off the distances shown by solid lines in plan, thus making M 1 equal to B 1, M 2 equal to B 2, etc. At right angles to L M draw M N, in hight equal to the straight hight of the article, as shown by X Y of elevation, and connect the points in M L with N. Also set off the distance D *d* from M, and draw N *d*. If E *d* was different in length from D *d*, this distance would be set off from M and a line drawn to N.

To develop the pattern first draw any line, as E B of Fig. 573, equal in length to N 1 of the diagram. With B of pattern as center, and N 2 of the diagram of triangles as radius, describe a small arc, which intersect with another arc struck from E of pattern as center and E 2 of plan as radius, thus establishing point 2 of pattern. Proceed in this manner, using the distance between points in plan for the distance between similar points in pattern, and the hypothenuses of the triangles in the diagram in Fig. 572 for the distances to be set off from B of pattern on lines of similar number. Through the points thus obtained trace a line, as shown by E D. With B of pattern as center, and B *d* of plan as radius, strike a small arc, which intersect with another struck from D of patterns as center, and N *d* of diagram as radius, thus establishing the point *d* of the pattern. Draw D *d* and *d* B. With B of the pattern as center, and B *e* of the plan as radius, strike a small arc, which intersect with another struck from E as center, with a radius equal to N *d* of the diagram of triangles. Draw E *e* and *e* B; then E *e* B *d* D will be the pattern for one-quarter of the article.

In performing the work of development of the pattern it will be found convenient as well as more accurate to use two pairs of compasses, one of which should remain set to the space used in dividing the curve E D of the plan, while the other may be changed to the varying lengths of the hypothenuses in the diagram of triangles.

PROBLEM 179.

Pattern for an Article Forming a Transition from a Rectangular Base to a Round Top, the Top Not Being Centrally Placed Over the Base.

In Fig. 574, F G H J of the plan represents the bottom of the article and A B D E the top. Below the plan is projected a front elevation and at the right a side elevation, like points in all the views being lettered the same. An inspection of the drawing will show that each side of the article consists of a triangular piece whose base is a side of the rectangle and whose vertex lies at a point in the circle of the top, the four vertices marking the division of the circle into quarters, and four quarters of inverted oblique cones whose bases are the quarter circles of the top and whose apices lie at the corners of the rectangle. A comparison between this figure and the one shown in Problem 177 will show that the conditions existing in either one of the corner pieces in this case are exactly the same as in the former problem, but that while in Problem 177 the four corners are alike, in the present instance the four corners are all different, and that therefore the pattern for each corner piece, as well as that for each of the flat sides, must be obtained at a separate operation, all being finally united into one pattern.

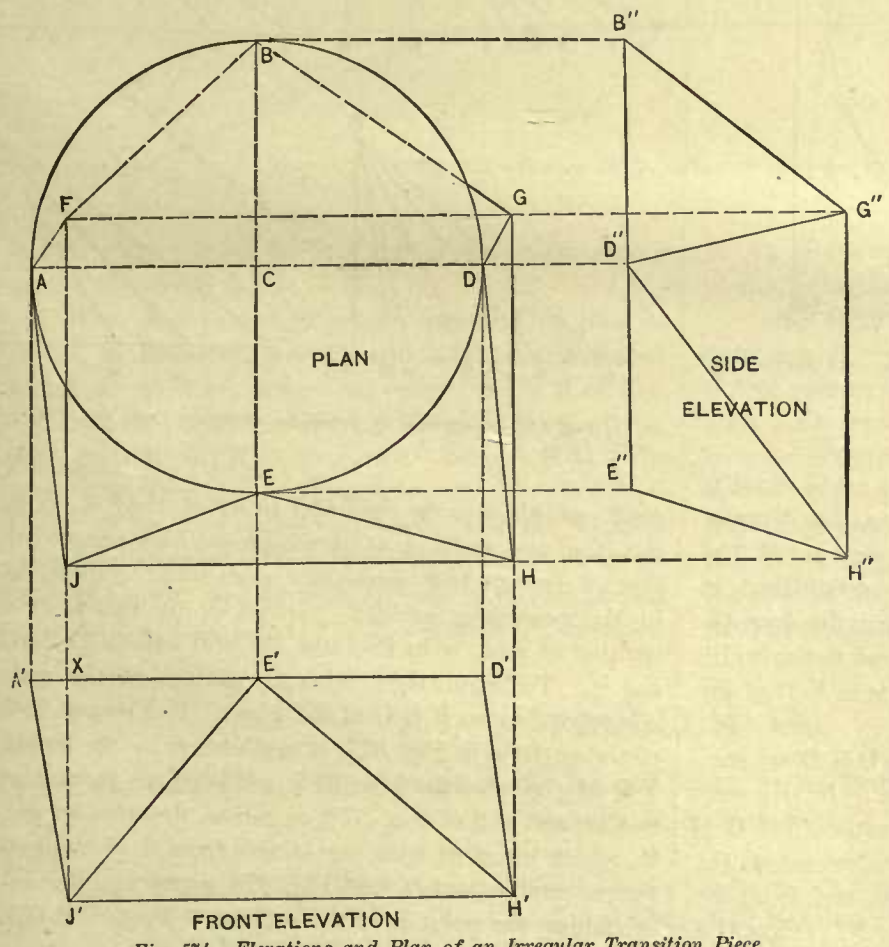


Fig. 574.—Elevations and Plan of an Irregular Transition Piece.

Divide the plan of the top A B D E into any convenient number of equal spaces in such a manner that

each quarter of the circle shall contain the same number of spaces and from the points of division in each quarter draw lines to the adjacent corner of the rectangle of the base, all as shown in Fig. 575. Thus lines from the points in E D are drawn to H and lines from points in D B are drawn to G, etc.

The next operation will be to construct the four diagrams of triangles (one for each corner piece) shown in Fig. 576, of which these lines are the bases. Accordingly lay off at any convenient place the line H L, Fig. 576, equal to the straight hight of article, as shown by J′ X in Fig. 574. From the point H, and at right angles to L H, draw the line H M, and, measuring from H, set off the length of lines in E D

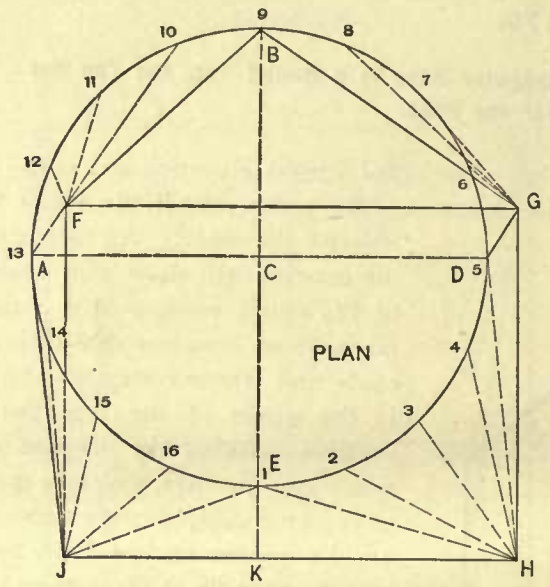


Fig. 575.—Plan of Irregular Transition Piece with Surface Divided into Triangles.

H of the plan, Fig. 575. Thus H 1 is made equal to H E of the plan, H 2 is made equal to the distance H 2 of the plan, and H 3 is equal to distance H 3 of the plan, etc. From the points thus established in M H draw lines to L, as shown. Then the hypothenuses L 1, L 2, L 3, etc., will correspond to the width of the pattern, measured between points in E D of top and H in the base.

The triangles for the corner piece D G B are constructed in the same general manner. N G corresponds to the hight J′ X of the elevation. O G is drawn at right angles to N G, on O G are set off the lengths of lines in D G B of the plan, and from the points thus obtained lines are drawn to N. Thus G 5 of the diagram is equal to G 5 of the plan, G 6 of the diagram is equal to G 6 of the plan, etc. The triangles in P Q F correspond with the lines in A F B of the plan, as do those in S R J with the lines A J E in the plan. Before commencing to describe the pattern the seam or joint may, for convenience, be located at K E of the plan. The real length of the line K E of the plan is given by H″ E″ in the side elevation, Fig. 574, or the distance E K can be set off, as shown by H K in Fig. 576. The dotted line K L will then be the distance from K in the base to E in the top.

As it is necessary in obtaining the pattern for the entire envelope that the patterns of the parts shall suc-

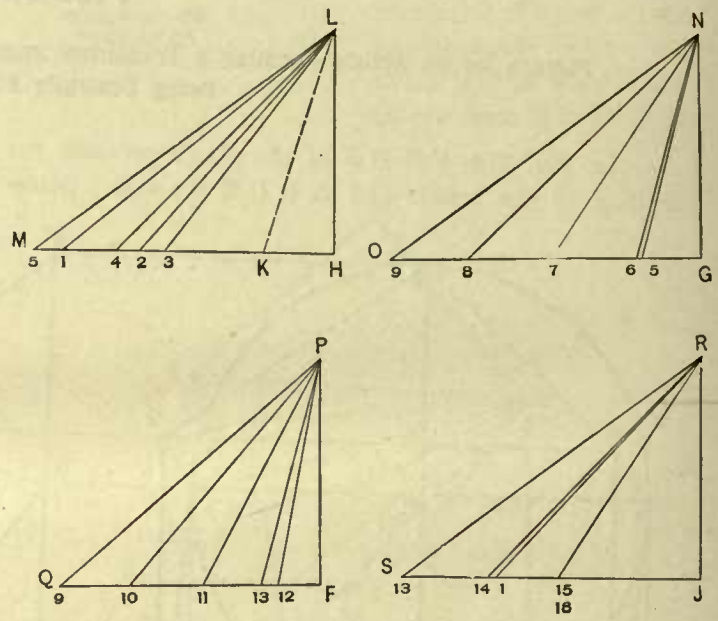


Fig. 576.—Diagrams of Triangles Obtained from Fig. 575.

ceed one another in the order in which they occur in the plan, the method of development here adopted is that of constructing separately each small triangle, as in the preceding problem, instead of by means of a number of arcs, as in Problem 177 and others preceding it. To begin, then, with the pattern of the part corresponding to F B G of the plan. The length F G of the pattern, in Fig. 577, is established by the length F G of the plan in Fig. 575. With F of pattern as center, and P 9 of Fig. 576 as radius, describe an arc, B, which intersect with one struck from G of the pattern as center, and N 9 of Fig. 576 as radius, thus establishing the point B of the pattern. Then F B G is

the pattern for that part of the article shown by F B G of the plan. From G of pattern as center, with radii corresponding to the hypothenuses of the triangles shown in O N G of Fig. 576, strike the arcs shown. Thus G 8 of the pattern is equal to N 8, G 7 of the pattern is equal to N 7, etc. With the dividers set to the same space used in stepping off the plan, with B or 9 of the pattern as center, strike a small arc intersecting arc 8 previously drawn, thus locating the point 8. From 8 as center intersect arc 7, and so continue, locating the points 6 and 5. Through the points thus obtained can be traced the line B D. Then

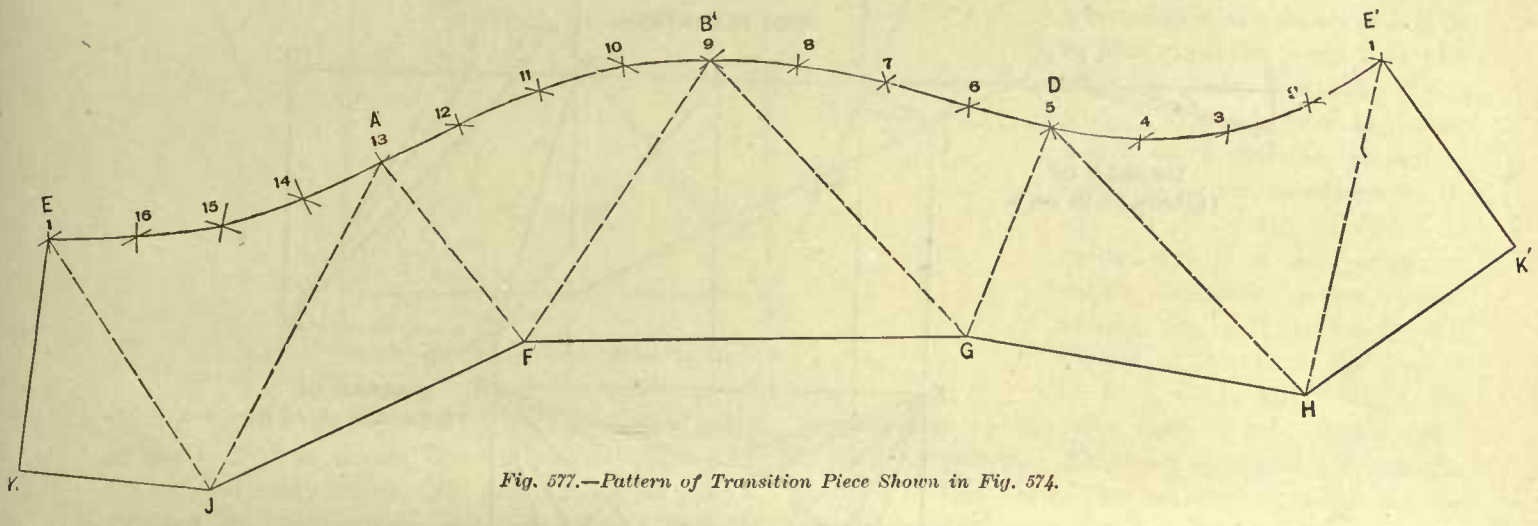


Fig. 577.—Pattern of Transition Piece Shown in Fig. 574.

G B D is the pattern for that part of the article shown on the plan by G B D.

With G of pattern as center, and G H of plan as radius, strike a small arc, H, which intersect with one struck from D of pattern as center and L M of Fig. 576 as radius, thus establishing the point H of pattern. Connect G H and H D, as shown. Then G H D is the pattern for that part of the article shown in plan by G H D. With H of pattern as center, and the hypothenuses of triangles in M L H of Fig. 576 as radii, strike arcs, as shown, making H 4, H 3, H 2, H 1 of pattern equal to L 4, L 3, L 2, L 1 of the diagram of triangles. With the dividers set to the same space as was used in stepping off the plan, and commencing at 5, intersect each succeeding arc from the point obtained in the one before it, as shown by the figures 4, 3, 2, 1. Trace a line through the points thus obtained, and connect E′ H, as shown. Then E′ D H is the pattern for that part of the article shown on plan by E D H. With H of pattern as center, and H K of plan as radius, describe a small arc, which intersect with one struck from E′ of pattern as center, and L K of Fig. 576, or what is the same, E″ H″ of Fig. 574, as radius, thus establishing the point K′ of the pattern. Connect H K′ and K′ E′, as shown, which gives the pattern for that part of the article shown on plan by H K E.

The radii for striking the arcs in A F B of the pattern are found in O P F of Fig. 576. The length F J of pattern is established by the length F J of the plan. The radii for striking the arcs in A J E of pattern are found in S R J of Fig. 576. J K of the pattern corresponds with J K of the plan, and E K of the pattern corresponds with L K of Fig. 576. Thus E A B D E′ of the pattern is the stretchout of E A B D of the plan of the top, as K J F G H K′ of the pattern is the stretchout of K J F G H of the plan of the base.

PROBLEM 180.

The Pattern for a Collar Round at the Top and Square at the Bottom, to Fit Around a Pipe Passing through an Inclined Roof.

Let A B D C of Fig. 578 represent the side elevation of the pipe and C D E F the side view of the collar, fitting against the pitch of the roof shown by G H. Construct a plan below the elevation, as shown, making J K M L the plan view of the pipe and N O P R the plan view of the collar on a horizontal line, giving the

collar an equal projection at the bottom on the four sides, as shown. Through the center point X in plan draw a line parallel to N R, intersecting the circle at K and L; likewise through the center X, and parallel to O N, intersect the circle at J and M. From J and K draw lines to the corner N; likewise from J and L, L and M, and M and K, draw lines to the corners R, P and O. It will be seen that by this operation the collar has been divided in such a manner that the four corner pieces are portions of oblique cones whose apices lay at the corners of the collar, while the side pieces between are simply flat triangular pieces of metal. The dotted lines connecting the plan with the elevation show corresponding points in the two views.

Divide the quarter circles K J and J L into any convenient number of equal spaces, as shown by the small figures, and from points on each draw lines to the corners N and R. Then will these lines represent the bases of a series of right angled triangles, whose hypothenuses will give the correct distances across the pattern of the collar. To construct these triangles proceed as follows: Upon C Y extended assume any point, as S, at which erect the perpendicular S T, equal in hight to the cone C Y F, as shown by the dotted line from F. From S on S C set off the lengths of the several lines in K N J of the plan, as shown by 1′, 2′, 3′, etc., and from these points draw lines to T. In the same manner construct the diagram of triangles shown at the right. At U upon the line Y D extended erect the perpendicular U V, equal in hight to the cone Y D E, as shown by the dotted line E V. From U on U D set off the lengths of the lines in J R L and draw the hypothenuses, as shown.

To develop the pattern, first draw any horizontal line, as A A′ of Fig. 579, equal in length to P R in plan of Fig. 578. With A and A′ as centers, and the

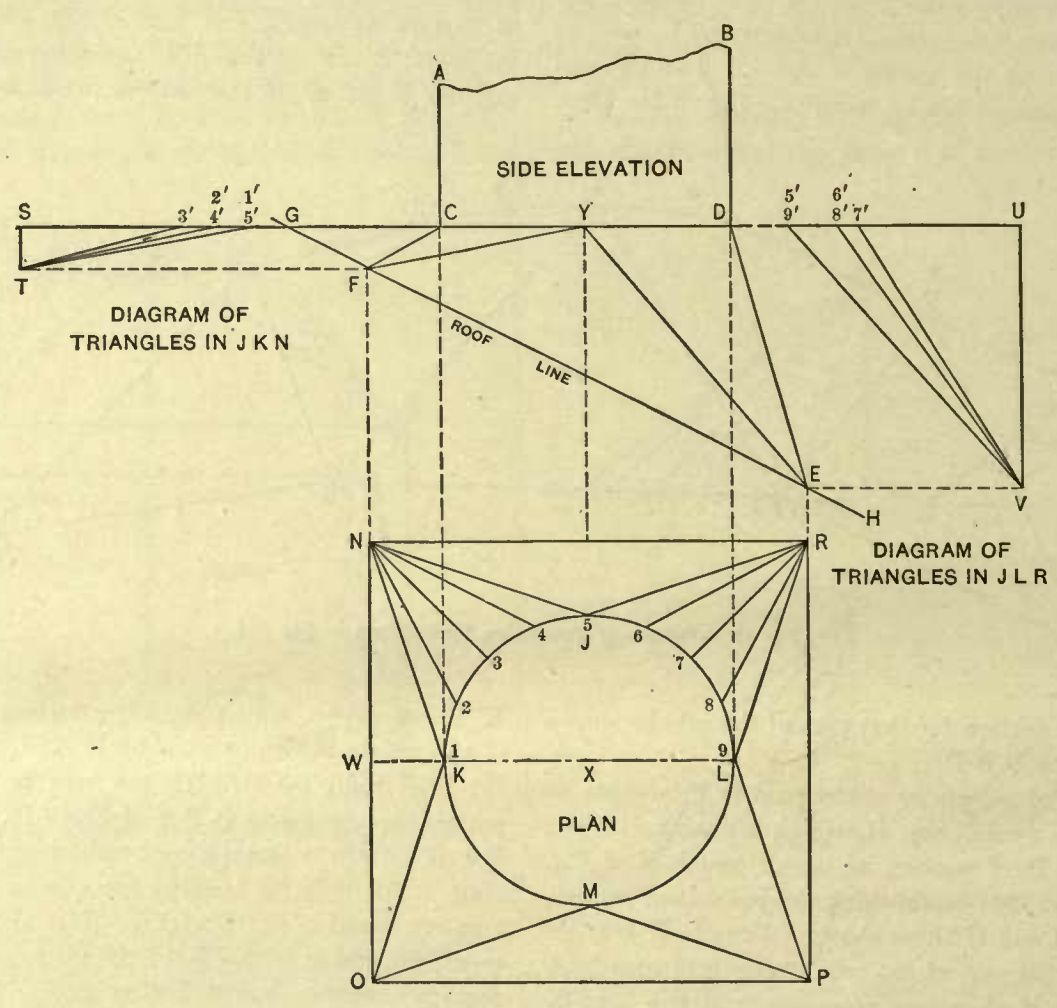


Fig. 578.—Plan and Side Elevation of a Collar to Fit Around a Pipe Pa sing throu h an Inclined Roof.

hypothenuse V 9′ of Fig. 578 as radius, describe arcs intersecting each other at 9. Now, with 9 of the pattern as center, and 9 8 of the plan as radius, describe the arc 8; then with V 8′ of Fig. 578 as radius, and A of the pattern as center, describe an arc, intersecting the arc previously drawn, thus establishing the point 8. Proceed in this manner, using alternately first the divisions on the quarter circle L J in plan, then the hypothenuses of the triangles whose bases are shown by the lines in J L R, until the point 5 in pattern has been obtained. Draw a line from 5 to A in Fig. 579. Then with A as center, and E F in side elevation, Fig. 578, as radius, describe an arc, shown at C of Fig. 579, and with 5 of the pattern as center, and the hypothenuse T 5′ of Fig. 578 as radius, describe an arc intersecting the previous arc at C. Draw a line from 5 to C. Now proceed as above described, using alternately first the spaces on the quarter circle in J K in plan, then the hypothenuses of the triangles whose bases are shown in J K N in plan, until the point 1 in pattern has been obtained. Then with C of the pattern as center, and W N of the plan as radius, describe an arc, as shown at D, and with F C in side elevation as radius, and 1 of the pattern as center, describe an arc, intersecting the arc previously described at D. Draw the lines 1 D, D C, C A, and through the intersections of the arcs trace a line, shown from 1 to 9 on pattern. This will complete one-half the pattern. The entire pattern may be completed by duplicating the part 1 5 9 A C D and adding the same to that already obtained in such a manner that the side 9 A will coincide with 9 A¹, as shown by 9 5′ 1′ D¹ C¹ A¹.

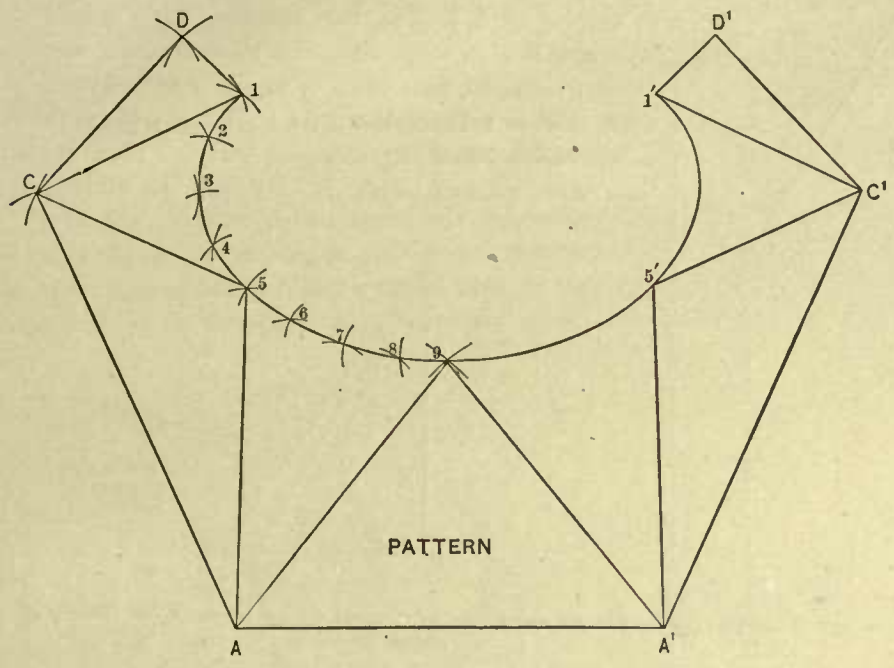


Fig. 579.—Pattern of Collar Shown in Fig. 578.

PROBLEM 181.

The Pattern for a Flaring Article Round at the Base and Square at the Top.

The shape shown in Fig. 580 differs from that treated in Problem 176 principally in the fact that the round end is larger than the rectangular end instead of smaller as in Fig. 566; the conditions involved are, however, exactly the same as in the other problem and consequently the method of obtaining the pattern must be similar. F G H J, in Fig. 580, represents the plan of the base, K L M N that of the top, and A B C E the elevation of a side of the article. Through O, the center of the circle of the base, draw the diameters G J and F H parallel to the sides of the top. From the four points thus obtained in the circumference of the base draw lines to the angles of the top, as shown by G M and H M, H N and J N, etc. It will be seen from this that the envelope of the article consists of four flat triangles, of which L G M is a plan and B D C the elevation, and four rounded corners, either one of which, as J N H, is a portion of

an oblique cone of which J H is the base and N the apex.

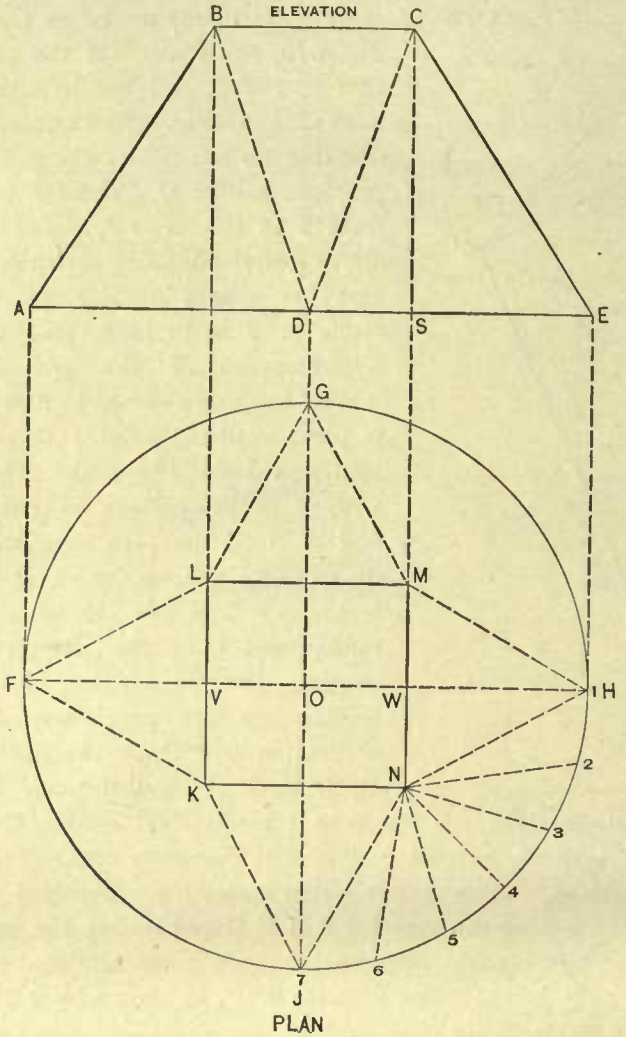


Fig. 580.—Plan and Elevation of a Flaring Article, Round at the Base and Square at the Top.

To obtain the pattern first divide the quarter plan of base J H into any convenient number of parts, as indicated by the small figures, and connect these points with N, as shown. To obtain the distance from points in J H of base to N of top it will be necessary to construct the diagram of triangles shown in Fig. 581. Draw any line, as R P, in length equal to the hight of the article, as shown by S C in Fig. 580. At right angles to R P draw P Q, and on P Q lay off the lengths of lines in J H N. Thus make P 1 equal to N 1 of the plan, P 2 equal to N 2, etc. Connect the points in P Q with R. The hypothenuses thus obtained give the true distances from the points in the base to N in the top.

From any convenient point, as N in Fig. 582, as center, with radius R 1 of Fig. 581, describe an arc, as shown by 1 7. In like manner, with radii R 2, R 3 and R 4 of Fig. 581, describe arcs, as shown. Draw a straight line from N to any convenient point upon the arc 1 7, as shown by N H. Set the dividers to the space used in stepping off the plan of the base and, starting with H, lay off the stretchout,

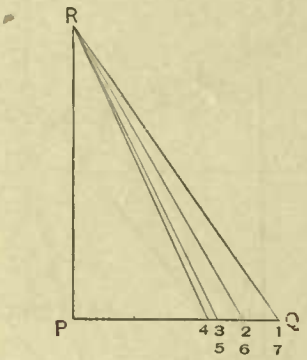


Fig. 581.—Diagram of Triangles Used in Obtaining Pattern of Article Shown in Fig. 580.

stepping from arc to arc, as shown. A line traced through these points will form the pattern for as much of the article as shown by J N H of the plan. With N of pattern as center, and N K of plan or B C of elevation as radius, describe a small arc, K, which intersect with an arc struck from J of pattern as center and J N as radius. Connect J K and K N, which completes the pattern for J K N of the plan. J K F of pattern is the same as J N H, and can be obtained in the same manner, or by any convenient means of duplication. With N as center, and N W of plan as radius, describe a small arc, which intersect with one

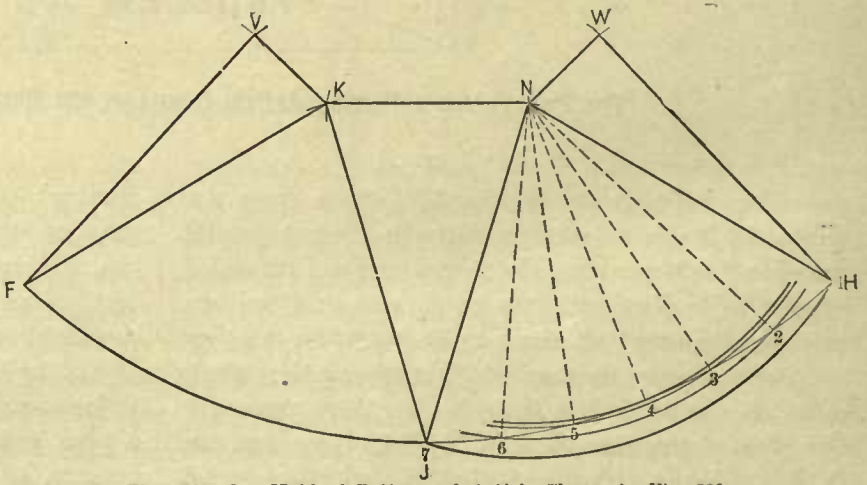


Fig. 582.—One-Half of Pattern of Article Shown in Fig. 580.

struck from H as center, and E C of elevation as radius. Connect H W and W N, thus producing the part of pattern corresponding to N W H of the plan. F K V of pattern is obtained in a similar manner. Then V K N W H J F is the pattern for one-half of article.

PROBLEM 182.

Pattern for an Article Rectangular at One End and Round at the Other, the Plane of the Round End Not Being Parallel to that of the Rectangular End.

In Fig. 583 are shown front and side views and plan of an article forming a transition between a rectangular pipe at one end and a round pipe at the other, and forming at the same time an angle between the two pipes. A E F C of the front view shows the size of the rectangular pipe, while G B H D shows the opening to receive the round pipe. In the side view *a c* shows the vertical rectangular end, and *b d* shows the angle at which the round end is placed, *b l d* being a half profile of the round end. As will be seen by an inspection of the front view, each quarter of the circular opening is treated as the base of a portion of a scalene cone whose apex is in the adjacent angle of the rectangle, the intermediate surfaces being flat triangular pieces. Thus B G and G D are the quarter bases of scalene cones whose apices are respectively at A and C; A B E and C D F are triangles whose altitudes or profiles are shown respectively by *a b* and *e d* of the side view; and A G C is a triangle whose profile appears at *o u* in the plan.

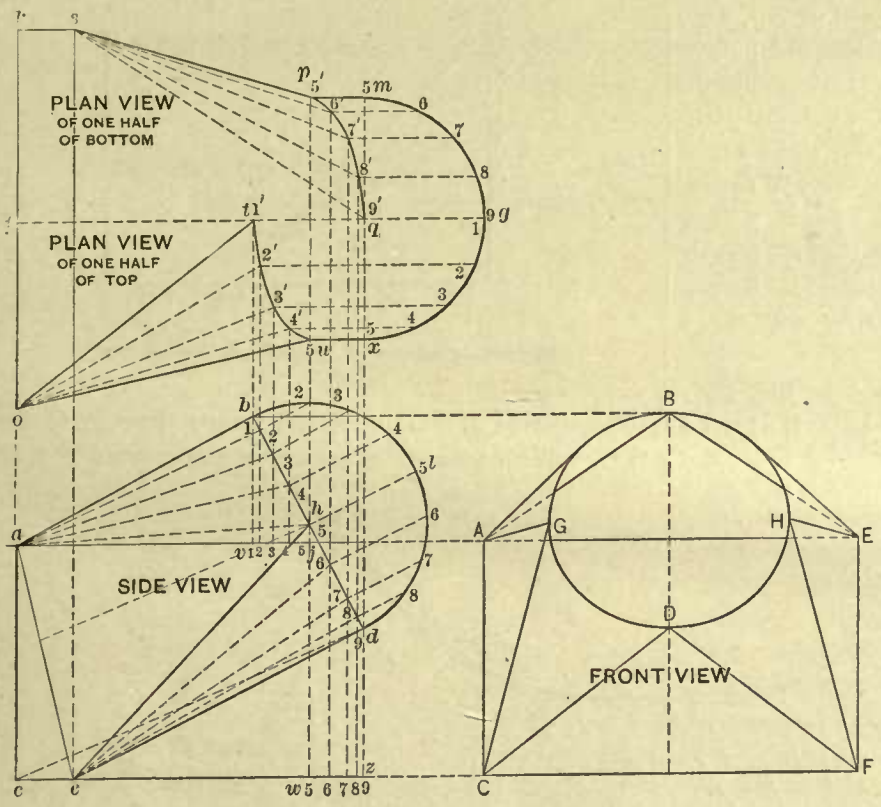


Fig. 583.—Front and Side Views and Plan of an Article Forming a Transition Between a Rectangular Pipe and a Round Pipe, at an Angle.

Divide each quarter of the profile *b l* and *l d* of Fig. 583 into any number of equal spaces, as shown by the small figures; also draw a duplicate of this half profile in proper relation to the plan, as shown by *m g x*, which divide as before, numbering the points in each to correspond, as shown. From the points in *b l p* drop lines at right angles to *b d*, cutting the same. From the points in *m g x* carry lines indefinitely to the left parallel to the center line *g f*, and intersect them by lines of corresponding number erected vertically from the points in *b d*. A line traced through the points of intersection will give a correct plan view of the opening in the round end. To avoid confusion of lines the intersections from the points between *b* and *h* or the upper half of the opening are shown only in the near or lower half of the plan from *t* to *u*, while the points belonging to the lower half (*h* to *d*) are shown only in the further half of the plan from *p* to *q*.

From each of the points in *p q* of the plan draw lines to *s*, which is the projection of *e* of the side view or apex of the cone in the lower half, and from the points in *t u* draw lines to *o*, the apex of the cone of the upper half of the article. These lines represent only the horizontal distances from *s* and *o* to the points in the opening *t u q p* of the plan or B G D of the front

view. To ascertain the real distances between these points it will be necessary to first ascertain their vertical hights from an assumed horizontal plane and then to construct from these measurements a series of right angled triangles whose hypothenuses will give the desired distances.

From the points in *b h* of the side view drop lines vertically, cutting a horizontal line drawn from *a*, as shown between *v* and *j*; and from the points in *h d* drop lines to *w z* drawn horizontally from *e*. To construct the triangles required in the top part, first draw the right angle R O K, as shown in Fig. 584, and from O on O R set off the length of lines in *b h j v* of side view, as indicated by the small figures. From O on O K set off the length of lines in *o t u* of plan of top, also as indicated by the small figures. Connect the points in O R with those of similar number in O K, as shown. To obtain the triangles required for the bottom part, proceed in a similar manner. Draw the right angle W S L, as shown in Fig. 585. From S on S W set off the length of lines in *h d z w* of side view, as indicated by the small figures. From S on S L set off the length of lines in *s p q* of plan of top, also as indicated by the small figures. Connect the points in S W with those of similar number in S L, as shown.

For the pattern proceed as shown in Fig. 586. Draw the line O O′, in length equal to A B of front view or *o k* of plan. Bisect O O′ in C, and erect the perpendicular C D, in length equal to *a b* of side view, and draw O D, D O′. These lines are equal in length to R K of first diagram of triangles. With O of pattern as center, and 2 2′ in R O K as radius, describe a small arc, 2, which intersect with one struck from point D of pattern as center, and *b* 2 in *b l* of profile as radius, thus establishing point 2 of pattern. Proceed in this

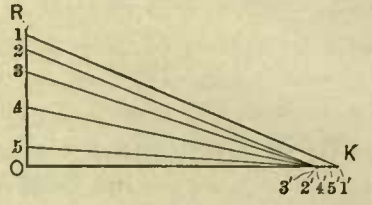


Fig. 584.—Diagram of Triangles in Top Half.

manner, using the length of lines in R O K for distances from O of pattern, and the stretchout between points in *b l* of profile of side view for the distance between points in D G of pattern; then draw D G and G O. With point G of pattern as center, and 5 5′ in

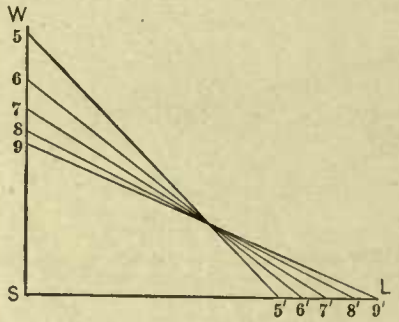


Fig. 585.—Diagram of Triangles in Bottom Half.

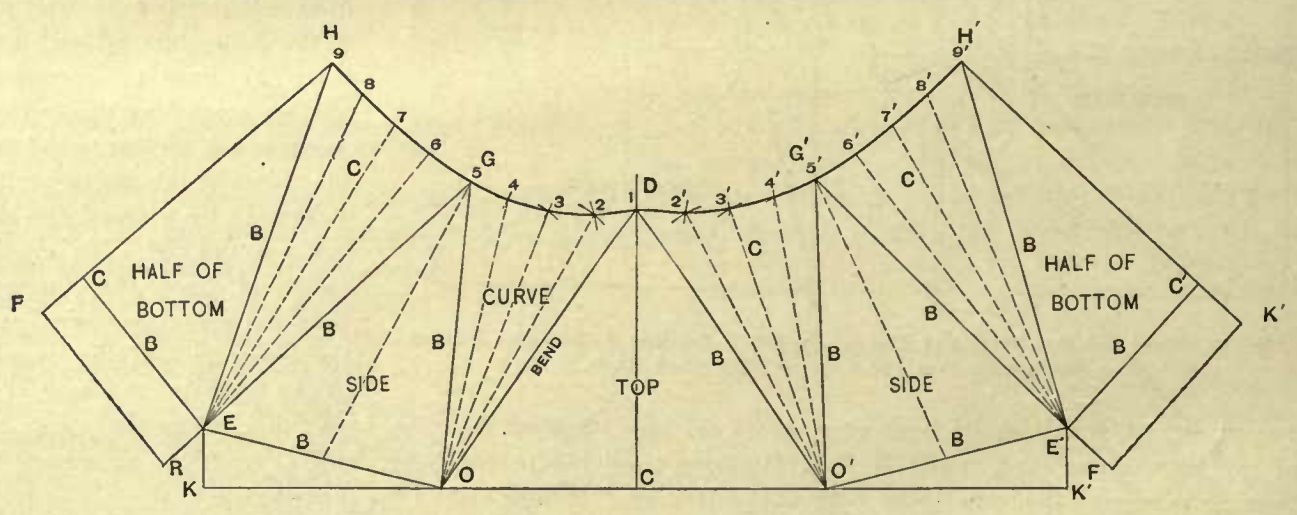


Fig. 586.—Pattern for Transition Piece Shown in Fig. 583.

W S L of triangles as radius, strike a small arc, E, which intersect with one struck from point O of pattern as center and *a e* of side view as radius, thus establishing point E of pattern. Draw G E and E O. With point E of pattern as center, and 6 6′ of triangle in

W S L as radius, strike a small arc, 6, which intersect with one struck from point G of pattern as center, and *l* 6 of profile as radius, thus establishing point 6 of pattern. Proceed in this manner, using the length of lines in W S L as distance from E of pattern, and the stretchout between points in *l d* of profile of side view for the distance between points in G H of pattern, and draw G H and H E. With point H of pattern as center, and *e d* of side view as radius, strike a small arc, C, which intersect with one struck from point E of pattern as center, and *o f* of plan, or C O of pattern, as radius, thus establishing point C of pattern; then draw H C and C E. From E and C erect the perpendiculars E R and C F, in length equal to *c e* of side view, and draw F R. With O of pattern as center, and *a c* of the side view as radius, strike a small arc, which intersect with one struck from E of pattern as center and *e c* of the side view as radius, thus establishing point K of pattern, and draw O K and K E. Then D G H F R E K C represents the half pattern of article. The other half can be obtained in the same manner or by duplication, as may be found convenient.

PROBLEM 183.

The Pattern for a Flaring Article, Round at Top and Bottom, the Top Being Placed to One Side of the Center, as Seen in Plan.

In Fig. 587, the elevation of the article is shown by A B D C, below which is drawn the plan of the same, corresponding parts in each being connected by the vertical dotted lines. There are two methods of triangulation available in the solution of this problem only one of which is given in this connection.

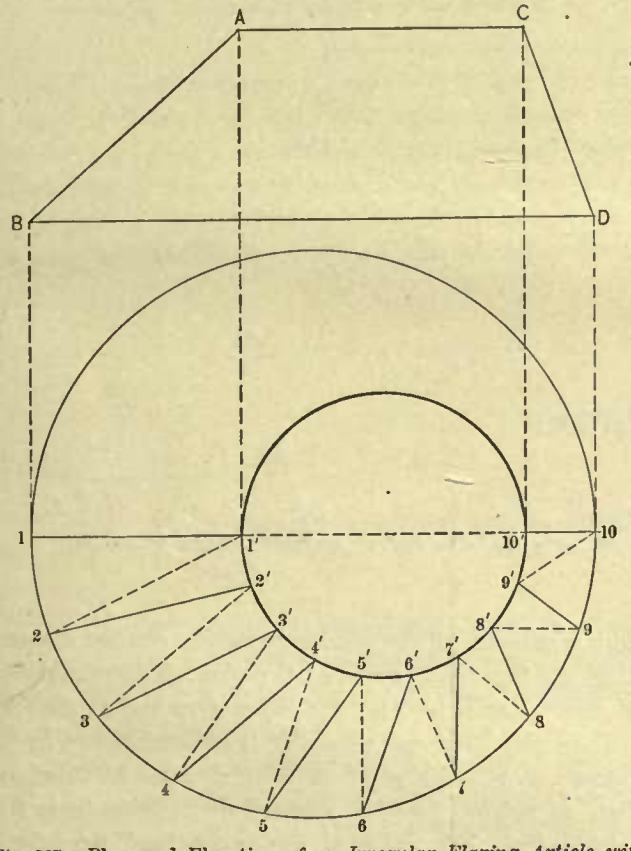


Fig. 587.—Plan and Elevation of an Irregular Flaring Article, with Lines of Triangulation Shown in the Plan.

Divide one-half of the circle representing the base of the article into any convenient number of spaces, as indicated by the small figures, 1, 2, 3, etc. In like manner divide the inner circle, which represents the top, into the same number of spaces, as indicated by 1′, 2′, 3′, etc. Between the points of like numbers in these two circles, as for example between 2 and 2′, 3 and 3′, etc., draw lines, as shown; also connect the points in the inner circle with points in the outer circle of the next higher number, as indicated by the dotted lines. Thus, connect 1′ with 2, and 2′ with 3, and so on, as shown. These lines just drawn across the plan are the bases of a number of right angled triangles whose altitudes are equal to the hight of the article, and whose hypothenuses, when drawn, will give the correct distances across the pattern, or envelope of the article, between the points in the top and those in the bottom in the direction indicated by the lines of the plan. The triangles having the solid lines of the plan as their bases are shown in Fig. 588, while those constructed upon the dotted lines are shown in Fig. 589, and are obtained in the following manner:

At any convenient point erect a perpendicular, E F, Fig. 588, which in length make equal to the straight hight of the article, as shown in the elevation. From F at right angles set off a base line of indefinite length. On this line, measuring from F, set off lengths equal to the several solid lines in the plan. For example, make the space F 10 equal to the length 10

10′ in the plan, and the space F 9 equal 9 9′ in the plan, and so on, until F 1 is set off equal to 1 1′ in the plan. From the points thus established in the base line draw lines to the point E. The triangles thus constructed will represent sections through the article on the solid lines in the plan. In other words, the several hypothenuses of the triangles shown in Fig. 588 are equal in length to lines measured at corresponding points on the surface of the completed article.

In like manner construct the triangles shown in Fig. 589, representing measurements taken on the dotted lines shown in the plan. Draw the perpendicular K G, equal in length to the straight hight of the article. From K lay off a horizontal base line indefinite in length, drawing it at right angles to K G. From K set off lengths equal to the dotted lines in the plan—that is, making the distance K 10 equal to the

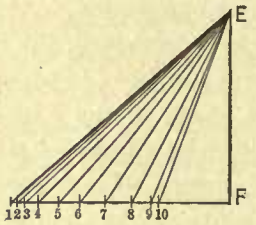


Fig. 588.—Diagram of Triangles Based upon the Solid Lines of the Plan in Fig. 587.

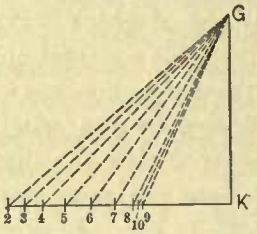


Fig. 589.—Diagram of Triangles Based upon the Dotted Lines of the Plan in Fig. 587.

distance 9′ 10 in the plan, and K 9 equal to the distance 8′ 9 in the plan, and so on until K 2 is made equal to the distance 1′ 2 in the plan. From the points thus established in the base line draw lines to the point G. Then the hypothenuses of the triangles thus constructed will equal measurements along the surface of the completed article at points corresponding to the dotted lines in the plan. With distances thus established upon the surface of the article, and with the stretchout of the required pattern determined at both top and bottom, it is easy to lay out the pattern upon the general plan of constructing a triangle when the three sides are given.

The development of the pattern can be begun at either end according to convenience, and the operation is conducted as follows: Assume any line, as 1 1′ of Fig. 590, which make equal in length to A B of the elevation, or, what is the same thing, equal to E 1 of Fig. 588, which is one side of the first triangle. The other two sides are respectively the distance 1 2 of the plan and the hypothenuse of the triangle shown in Fig. 589 corresponding to the line 2 1′ of the plan. Accordingly, take the distance 1 2 of the plan in the dividers, and from 1 as center describe a short arc. Then, taking the distance G 2 of Fig. 589 in the dividers, and with 1′ as a center, intersect the arc already struck, thus establishing the point 2 of the pattern.

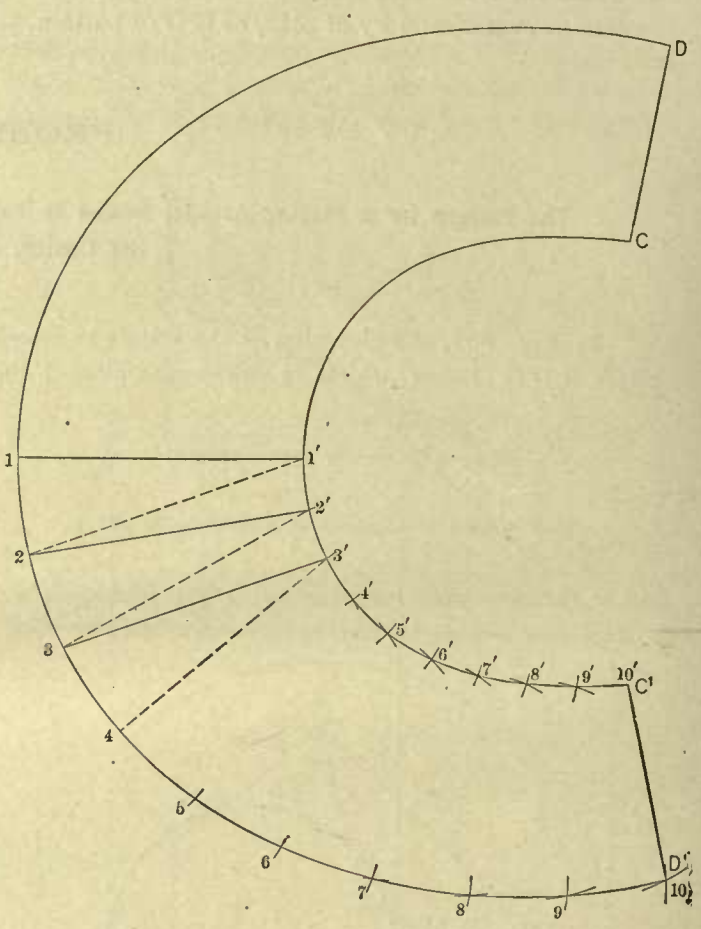


Fig. 590.—The Pattern of Article Shown in Fig. 587.

The elements of the second triangle are the distance 1′ 2′ on the inner circle of the plan, the hypothenuse of the triangle in Fig. 588 corresponding to the line 2 2′ in the plan and the side just established in the pattern 2 1′. From 1′ as center, with 1′ 2′ of the plan as radius, describe a short arc. Then from 2 as center, with E 2 of Fig. 588 as radius, describe a second arc, intersecting the one already made, thus establishing the point 2′. Proceed in this manner until triangles have been described adjacent to each

other, corresponding to the divisions first established in the plan. Then lines traced through the points thus established, as shown from 1 to 10 and from 1′ to 10′, will constitute the pattern of half the article. The other half may be obtained by any convenient means of duplication and may be added on to either end of the half already obtained, according as it is desired to make the joint at the widest or narrowest part of the pattern.

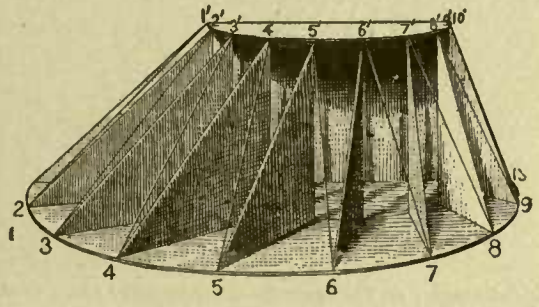


Fig. 591.—Model of One-Half the Article Shown in Fig. 587, Illustrating the Construction and Use of the Triangles.

In Fig. 591 is shown a model which may be constructed of thin metal and wires, or of cardboard and threads, according to convenience, which will assist the student in forming a correct idea of the relationship existing between the various lines drawn upon the plan and the lines of which the pattern is constructed. The top and bottom of the model are duplicates of the inner and outer circles of the plan. The piece forming the bottom should have the solid lines and the inner circle of the plan drawn upon it as a means of placing in position the several triangular pieces shown, which are duplicates of the several triangles shown in Fig. 588. These triangular pieces having been placed in position according to their numbers, and fastened at the top and bottom, their outer edges, or hypothenuses, will then represent the solid lines drawn across the pattern, and will bear the same relation or angle to the edges of the top and bottom pieces of the model that the solid lines of the pattern bear to the top and bottom outlines of the pattern. Finally, threads or wires having been attached, as shown, will represent the dotted lines drawn across the pattern, and will bear the same angle to the edges of the solid triangles, as measured upon the model, that the dotted lines of the pattern bear to the solid lines, as measured upon the pattern.

Since the top and the bottom of the shape here shown are both round and horizontal, the figure becomes that of the frustum of a scalene cone; and, therefore, its sides, if continued upward, would terminate in an apex which can be made the common apex of a number of triangles whose bases are the spaces upon the outer line of the plan. This method of solving the problem as applied to a full scalene cone is given in Problem 163, which see.

PROBLEM 184.

The Pattern for a Flaring Article, Round at Top and Bottom one Side Being Vertical.

In Fig. 592, A B C D shows the elevation of the article, below which E F G H shows the plan at the bottom and E J K L the plan of its top, both circles being tangent at the point E.

Divide the circle representing the plan of the top into any convenient number of equal spaces, as represented by the small figures between K L E in the diagram. In the illustration only one-half of the plan has been divided, which is sufficient for the purpose. Next divide a like portion of the plan of the base into the same number of equal parts, as shown by the figures between E H G. Connect these two sets of points, first by lines drawn between like numbers, as 1 and 1′, 2 and 2′, 3 and 3′, etc. In a like manner connect 1 of the inner circle with 2′ of the base, 2 with 3′, 3 with 4′, etc., all as shown by the dotted lines in the plan. These lines just drawn are the bases of a number of right-angled triangles, whose altitudes are equal to the vertical hight of the article, and whose hypothenuses, when obtained, will give the correct measurements across the pattern between the numbered points.

For a diagram of triangles representing the solid

lines in plan erect the vertical line P S in Fig. 593, equal to A B of elevation. Then at right angles from S lay off a base line, upon which set off distances, measuring from S, equal to the lengths of the several solid lines drawn across the plan in Fig. 592. Thus make S R equal to K G (1 1′) and S 2 to 2 2′, and so

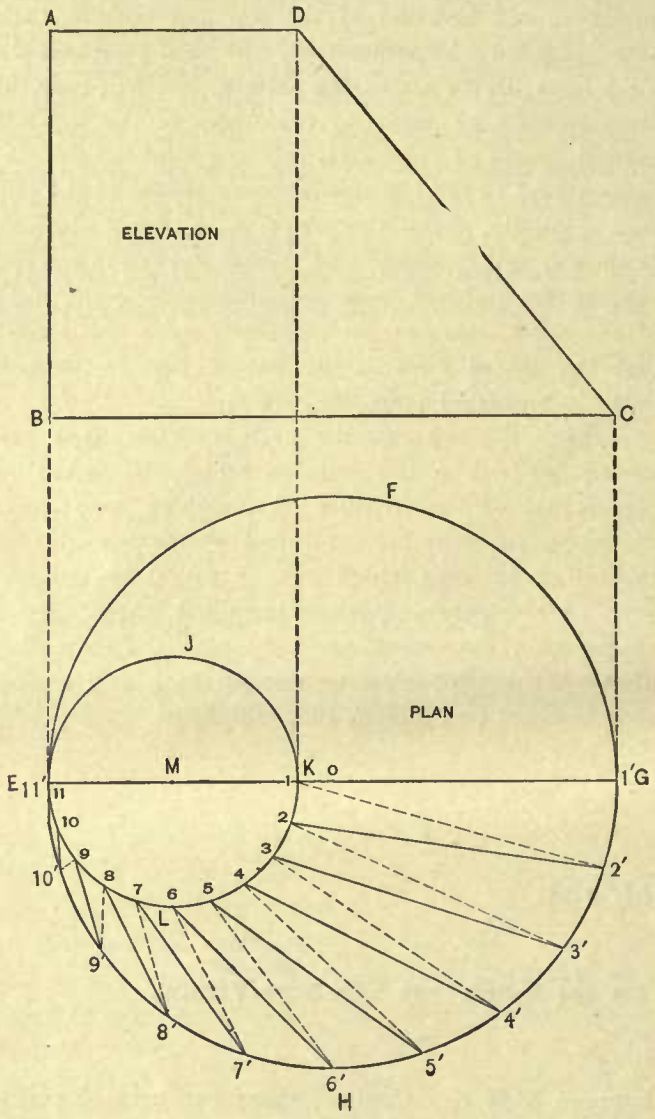


Fig. 592.—Plan and Elevation of Flaring Article, Showing Method of Triangulation.

on. From the points thus established in the base draw lines to the apex. Then the hypothenuses of the triangles will be equal to measurements on the surface of the finished article on lines drawn from the points in the base to corresponding points in the top. In the same way construct the diagram representing the triangles based on the dotted lines in plan, as shown in Fig. 594. Set off T V equal to the straight hight of the article. From V draw the horizontal line V U, upon which,

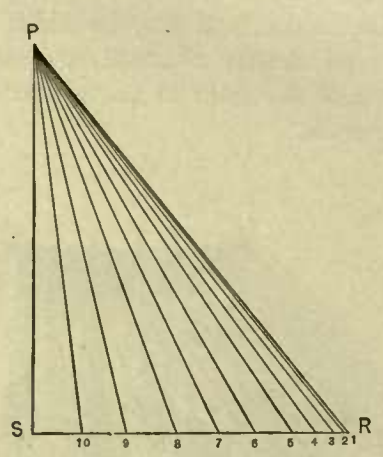


Fig. 593.—Diagram of Triangles Based upon Solid Lines in the Plan in Fig. 592.

measuring from V, set off distances equal to the length of the dotted lines across the plan. Thus make V 2 equal to 1 2′, V 3 equal to 2 3′, etc. From the points thus established in V U draw lines to the apex T. These lines will be equal to measurements upon the

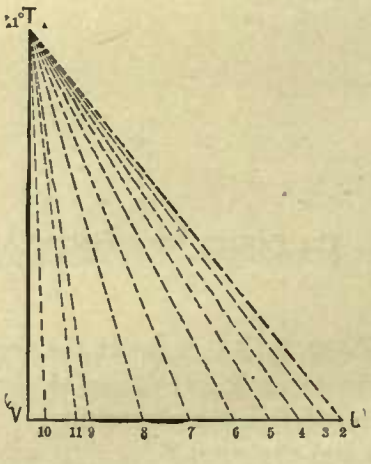


Fig. 594.—Diagram of Triangles Based Upon Dotted Lines in the Plan in Fig. 592.

surface of the finished article between the points connected by the dotted lines in the plan.

Having obtained the correct dimensions of all the

triangles assumed at the beginning of the work they may now be constructed consecutively, thus developing the pattern in the following manner: Assume any straight line, as D C of Fig. 595, which make equal to D C of the elevation, or, what is the same thing, P R of the diagram of triangles, Fig. 593. From C as a center, with a radius equal to 1′ 2′ of the plan, strike a small arc, which intersect with another small arc struck from D as center, with a radius equal to T 2 of Fig. 594, thus establishing the point 2′ of the pattern. From D as center, with a radius equal to 1 2 of the plan of the top, Fig. 592, strike a small arc and intersect it with another struck from 2′ of the pattern as center, and P 2 of Fig. 593 as a radius, thus establishing the point 2 in the top of the pattern. Proceed in this manner, using the hypothenuses of the triangles in Fig. 594 with the spaces in the outer curve of the plan, Fig. 592, to establish the points in the bottom curve of the pattern; and the hypothenuses of the triangles in Fig. 593 with the spaces in the inner curve of the plan to establish the points in the top curve of the pattern. Lines traced through the points of intersection, as shown from C to B and from D to A, will, with D C and A B, constitute the pattern for the half of the article shown by E H G K of the plan. The other half may be added, as shown, by any convenient means of duplication.

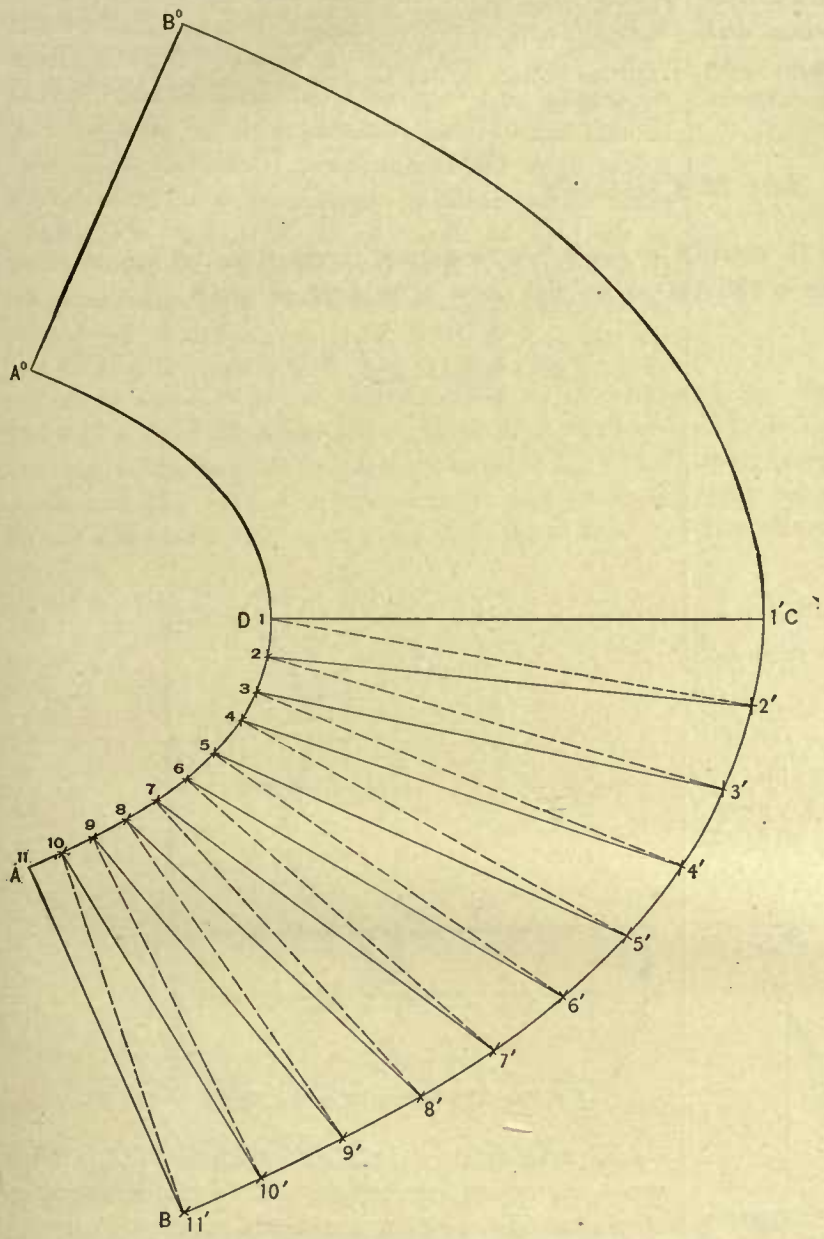


Fig. 595.—The Pattern of Flaring Article Shown in Fig. 592.

Since the top and the bottom of this figure are both round and horizontal, it becomes the frustum of a scalene cone, which permits of its being treated by a different, and perhaps simpler, method of triangulation, all of which is given in Problem 167, to which the reader is referred.

PROBLEM 185.

The Pattern of an Article having an Elliptical Base and a Round Top.

Fig. 596 shows the plan and elevation of the article for which the pattern is required. Divide one-quarter part of the plan of the base E G into any convenient number of equal spaces, and divide a corresponding part of the plan of the top L K into the same number of spaces, numbering the points of divi-

sion the same in both, as indicated by the small figures 1, 2, 3 and 1', 2', 3', etc. The article here shown possesses some of the general features of the cone in that it is tapering in its sides, but inspection will show that the slant or taper of its sides varies in different parts of its circumference, or in other words, that different

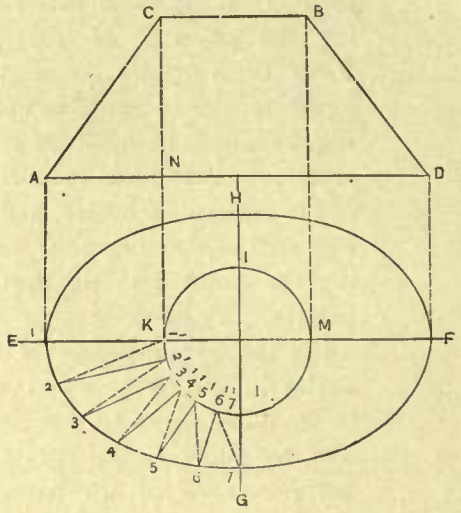


Fig. 596.—Elevation and Plan of Flaring Article with Elliptical Base and Round Top.

lines drawn through like numbers in the base and top would, if extended upward, meet the axis at different hights, hence some means must be devised for measuring the real distances between the points in the base and the points in the top, which may be accomplished in the following manner: First connect all points in the base in plan with points of the same number in

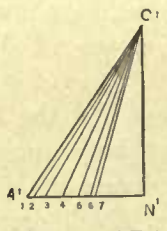


Fig. 597.—Diagram of Triangles Based upon Solid Lines of the Plan in Fig. 596.

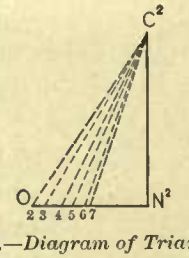


Fig. 598.—Diagram of Triangles Based upon Dotted Lines of the Plan in Fig. 596.

the top by means of a solid line, as shown upon the plan by lines 1, 1', 2, 2', etc. Also draw the intermediate dotted lines connecting alternate points, as shown in the engraving by 2 1', 3 2' 4 3', etc., thus dividing the entire surface of the article into triangles.

Construct a diagram, as shown by A' N' C', Fig. 597, in which the actual distance between corresponding points in base and top shall be shown. Make C' N' equalto the straight hight of the article, C N of the elevation. At right angles to it set off N' A', in length equal to the distance 1' 1 in plan. From N' set off also on N' A' spaces corresponding to 2' 2, 3' 3, 4' 4, etc., of the plan, and from each of these points draw a line to C', as shown. Then the lines converging at C' represent the distances which would be obtained by measurements made at corresponding points upon the article itself. Construct a like diagram of the distances represented in the dotted lines in the plan, as shown by C² N² O, Fig. 598. Make C² N² equal to C N of the elevation, and from N² set off at right angles the line N² O. Upon this line make the spaces N² 2, N² 3, N² 4, etc., equal to the length of the dotted lines 1' 2, 2' 3, 3' 4, etc., and from the

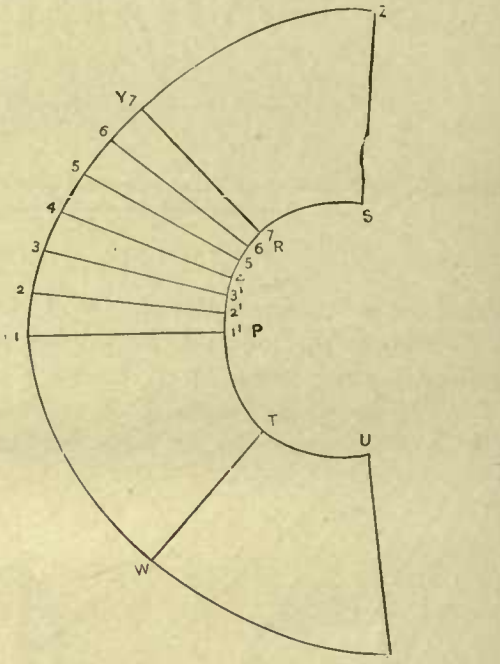


Fig. 599.—The Pattern of Article Shown in Fig. 596.

points thus obtained in N² O draw lines to C². Then these converging lines represent the same distances as would be obtained if measurements were made between corresponding points upon the completed article.

For the pattern, commence by drawing any line, as P X in Fig. 599, on which set off a distance equal to C' 1 of the first diagram, as shown by 1 1'. Then, with the distance from 1 to 2 of the plan for radius, and 1 in pattern as center, describe an arc, which intersect by another arc struck from 1' of the pattern as center, and C² 2 of the second diagram as radius, thus establishing the point marked 2 in the pattern. Next, with 1' 2' of the plan as radius, and from 1' of the pattern as center, describe an arc, which intersect by another

are drawn from 2 as center, and with C' 2 of the first diagram as radius, thus locating the point 2' of the pattern. Continue in this manner, locating each of the several points shown from X to Y and from P to R of the pattern, through the several intersections, tracing the lines of the pattern, as shown. Then X Y R P will be one-quarter of the required pattern. Repeat this piece three times additional, as shown by W X P T, V W T U and Y Z S R, reversing each alternate piece, thus completing the pattern.

PROBLEM 186.

Pattern for an Irregular Flaring Article which is Elliptical at the Base and Round at the Top, the Top being so Situated as to be Tangent to One End of the Base when Viewed in Plan.

In Fig. 600, let D G F E be the side elevation of the article and K N M one-half of the plan of the base. The half plan of the top is shown by K W L, the base and top being tangent in plan at the point K. The conditions and method of procedure in this problem do not differ materially from those of Problem 184.

Next construct the diagrams of triangles, as shown in Fig. 601 at the right of the elevation, making A U in hight equal to D E of the elevation, and lay off U T at right angles to it. Let A represent all points in the circle representing the plan of the top of the article. Lay off from U upon U T the distance from each of

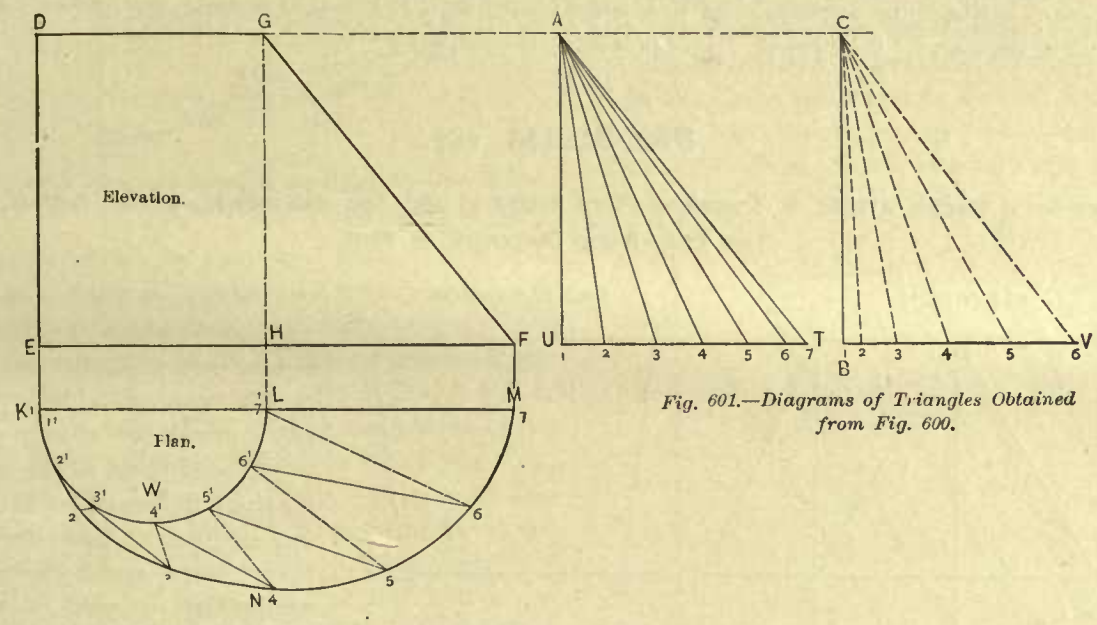


Fig. 601.—Diagrams of Triangles Obtained from Fig. 600.

Fig. 600.—Elevation and Plan of an Irregular Flaring Article with Elliptical Base and Round Top.

The surface of this article may be divided into measurable triangles in the following manner: Divide the plans of top and base into the same number of equal parts, as shown by 1, 2, 3, etc., in the base and 1', 2', 3', etc., in the top, and connect similar points in the two by solid lines, as shown by 6 6', 5 5', etc. Also connect each point in the plan of the top with the next lower number in the plan of the base, as shown by the dotted lines in the engraving, as 6 7', 5 6', etc.

the several points in the circle to the corresponding point in the ellipse. Thus make U 7 equal to 7' 7 of the plan, U 6 equal to 6' 6, etc., and draw the radial lines A 2, A 3, etc. In like manner construct a corresponding diagram, as shown by C B V, using for the spaces in B V the lengths of the dotted lines between the circle and the ellipse in the plan, and draw C 2, C 3, C 4, etc. By means of these two sets of lines, converging at A and C respectively, and the stretchouts of the two

curves of the plan, the actual dimensions of the triangles into which the surface of the article has been divided can be accurately measured.

These are to be used in describing the pattern as follows: At any convenient place draw the straight line P R in Fig. 602, in length equal to G F of the elevation, or, what is the same, equal to A 7 of the first diagram. As but half of the plan of the article is shown, the pattern will also appear as one-half of the whole shape, and therefore P R will form its central line. From P as center, with radius C 6 of the second diagram, describe an arc, which intersect by a second arc struck from R as center, with radius 7 6 of plan, thus establishing the point 6 of the pattern. Then with radius A 6 of the first diagram, from 6 of the pattern as center, describe an arc, which cut with another arc struck from 7^1 of the pattern as center, and 7^1 6^1 of the plan as radius, thus locating the point 6^1 of the pattern. Continue this process, locating in turn 5, 5^1, 4, 4^1, etc., until points corresponding to all the points laid off in the plan are established. Lines traced

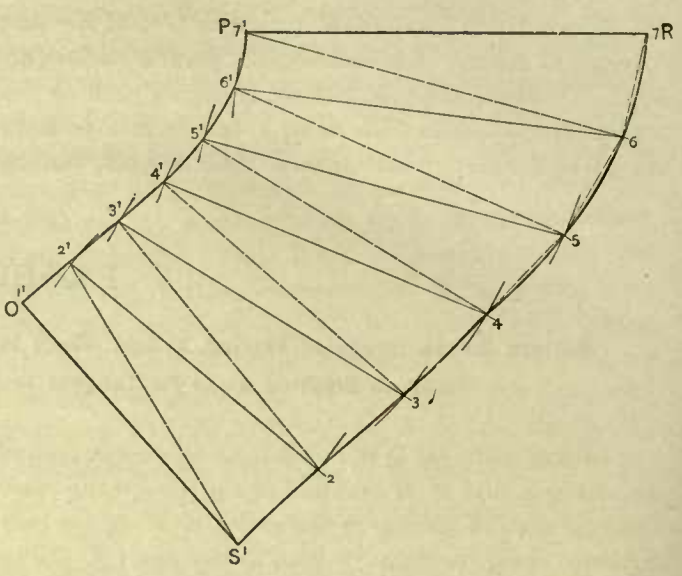


Fig. 602.—Pattern for Article shown in Fig. 600.

through the points 7, 6, 5, etc., and 7^1, 6^1, 5^1, etc., will, with P R and O S, form the pattern of one-half the article.

PROBLEM 187.

Pattern for a Flaring Article or Transition Piece Round at the Top and Oblong at the Bottom, the Two Ends Being Concentric in Plan.

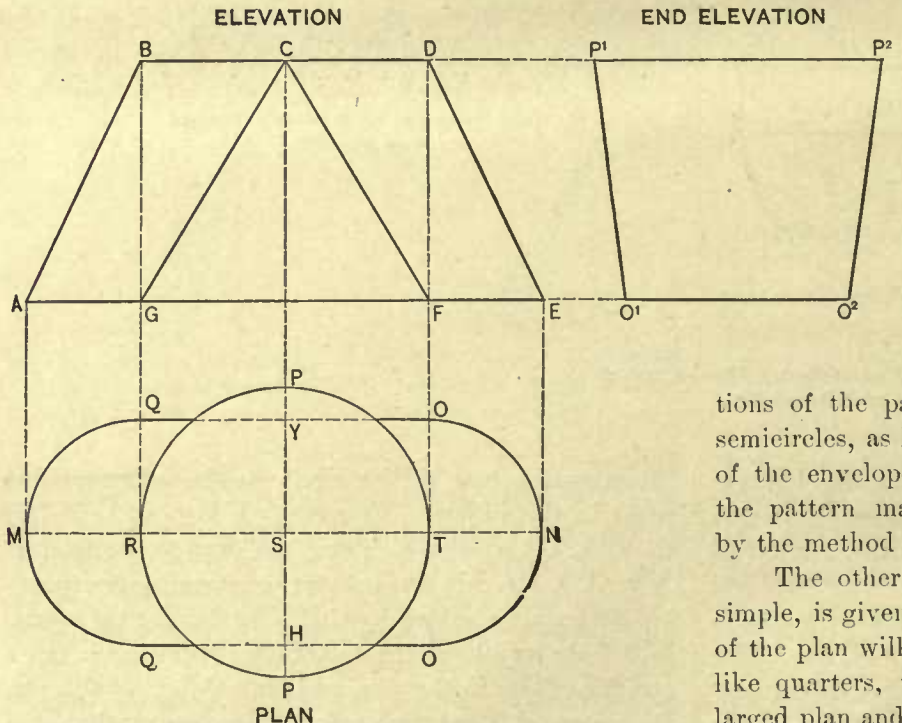


Fig. 603.—Plan and Elevations of Flaring Article Round at the Top and Oblong at the Bottom.

In Fig. 603 are shown the side and end elevations and the plan of an article which might form a transition between an oblong pipe below and a round pipe above. According to the conditions, as given in the engraving, the problem is capable of two solutions. Since the upper and lower bases are composed, either wholly or in part, of semicircles lying in parallel planes, those portions of the pattern of the article lying between the semicircles, as P O N O P, must necessarily form parts of the envelope of a scalene cone. Those portions of the pattern may therefore be obtained, if desirable, by the method employed in Problems 168 and 169.

The other solution, which is perhaps the more simple, is given in Figs. 604 to 606. An inspection of the plan will show that the article consists of four like quarters, therefore in Fig. 604 is shown an enlarged plan and elevation of one-quarter of the article. Divide P T and O N of the plan each into the

same number of equal parts, and connect the points in P T with those in O N, as indicated by the solid lines. Also connect points in the top with those in

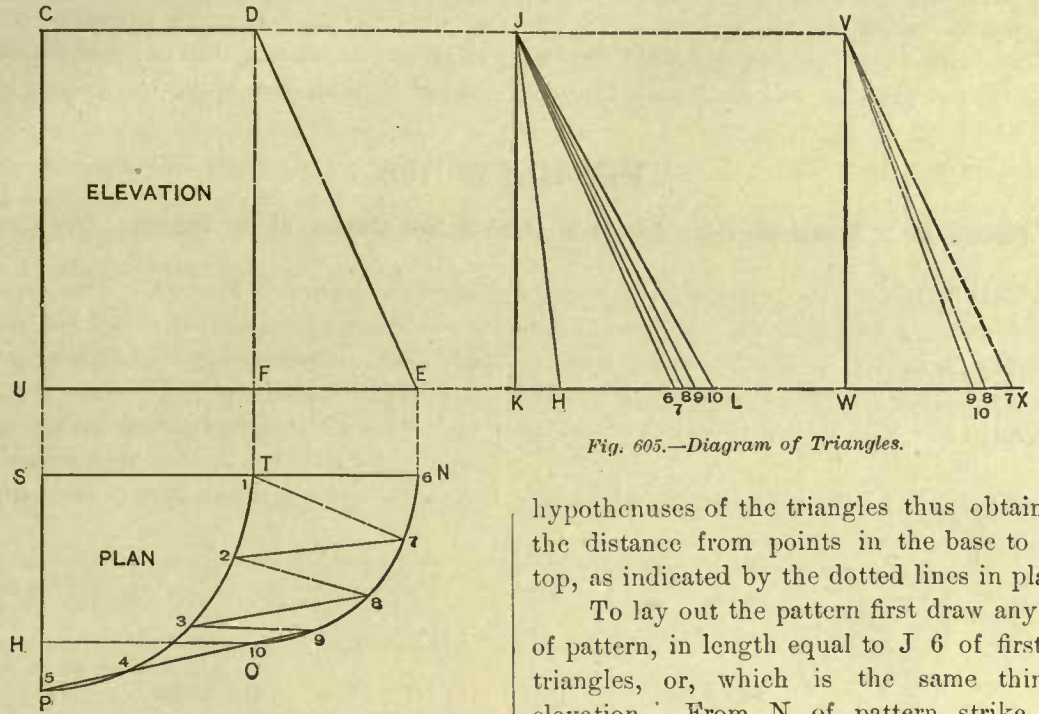


Fig. 604.—Quarter Plan and Elevation Enlarged, Showing Method of Triangulation.

the bottom, as shown by the dotted lines. These lines represent the bases of right angled triangles, the altitude of which will be equal to the straight hight of the article. For a diagram of the triangles representing the solid lines of the plan, draw any vertical line, as J K in Fig. 605, which make equal in hight to the hight of the article, as shown by the dotted line D F. From K, at right angles to J K, draw K L, upon which set off distances, measuring from K, equal to the lengths of the solid lines drawn across the plan. Thus make K 6 equal to T N and K 7 equal to 2 7 of plan, and so on. Also set off from K the distance H P of plan, as shown by K H. From the points thus established in K L draw lines to J. The hypothenuses thus obtained will give the distances across the finished article, as indicated by the solid lines of the plan.

The next step will be to construct a diagram of triangles that will give the distances between points in the base and top, as indicated by the dotted lines in plan. This diagram is constructed in a similar manner, as shown at the right in Fig. 605. Draw the right angle V W X, making V W equal to the straight hight of the article, and from W set off on W X the lengths of dotted lines in plan. Thus make W 7 equal to T 7 and W 8 equal to 2 8, and so on. From the points thus established in the base draw lines to V. The

Fig. 605.—Diagram of Triangles.

hypothenuses of the triangles thus obtained will give the distance from points in the base to points in the top, as indicated by the dotted lines in plan.

To lay out the pattern first draw any line, as T N of pattern, in length equal to J 6 of first diagram of triangles, or, which is the same thing, D E of elevation. From N of pattern strike a short arc

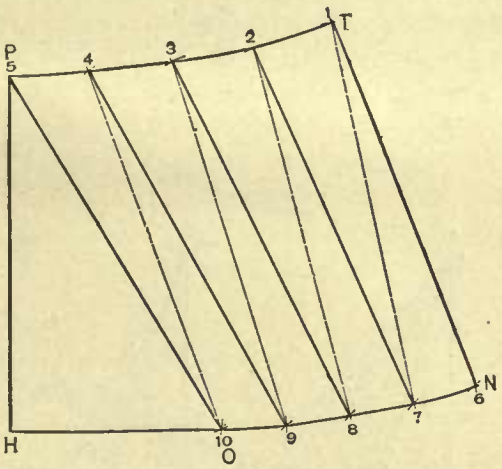


Fig. 606.—Quarter Pattern of Article Shown in Fig. 603.

with a radius equal to N 7 of the plan, as shown. From T of pattern as center, with radius equal to V 7 of the second set of triangles, intersect this arc, thus establishing the point 7 of pattern. From T, with radius equal to T 2 of the plan, strike a small arc, as shown, and intersect it with another from point 7 of pattern as center, with J 7 of the diagram of triangles as radius, thus establishing the point 2 in pattern.

Proceed in this manner, using alternately the hypothenuses of the triangles in V W X of Fig. 605, the spaces in plan of base O N, the hypothenuses of the triangles in J K L, Fig. 605, and the spaces in the plan of top, P T, in the order named, and as above explained. The resulting points, as indicated by the small figures in the pattern, will be points through which the pattern line will pass. For the pattern of triangle P H O of pattern, with O of pattern as center, and O H of plan as radius, strike a small arc in the direction of H. With P of pattern as center, and J H of the diagram of triangles as radius, describe another small arc intersecting the one just struck. Draw O H and H P, thus completing the quarter pattern.

PROBLEM 188.

Pattern for a Transition Piece Round at the Top and Oblong at the Bottom. Two Cases.

In Fig. 607 is shown the plan and elevations of a transition piece, constituting the *first case*, such as is frequently required in furnace work when it is necessary to connect a round pipe with another pipe of equal area but flattened into an oblong shape.

In Fig. 611 are shown the plan and elevations of a transition piece of the *second case*, answering the same general description as that given above, but differing only in the fact that the circle representing the top in the plan view does not touch the side of the line representing the bottom of the article. In other words, the side F H is slanting instead of vertical, as in the first case, shown in Fig. 607. The principle involved in developing the patterns of the two shapes is exactly the same, consequently the following demonstration will apply equally well to either Fig. 607 or 611, in each of which corresponding points are lettered the same. (It will be noticed that separate diagrams of triangles and a separate pattern corresponding to Fig. 611 have not been given. While in reality they would differ somewhat from those shown in Figs. 608 to 610, they would have the same general appearance, and in method of construction would be exactly the same, and therefore have not been considered necessary to the study of the problem.)

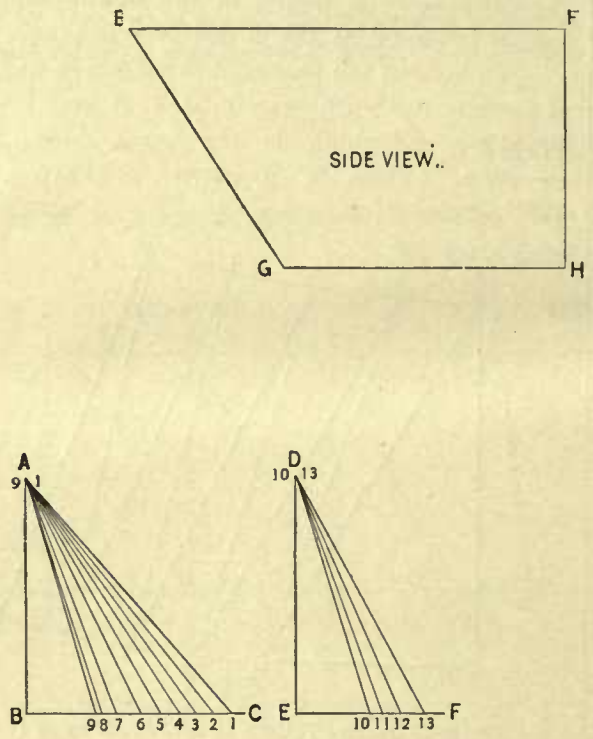


Fig. 608.—Diagrams of Triangles Based upon the Solid Lines of the Plan, Fig. 607.

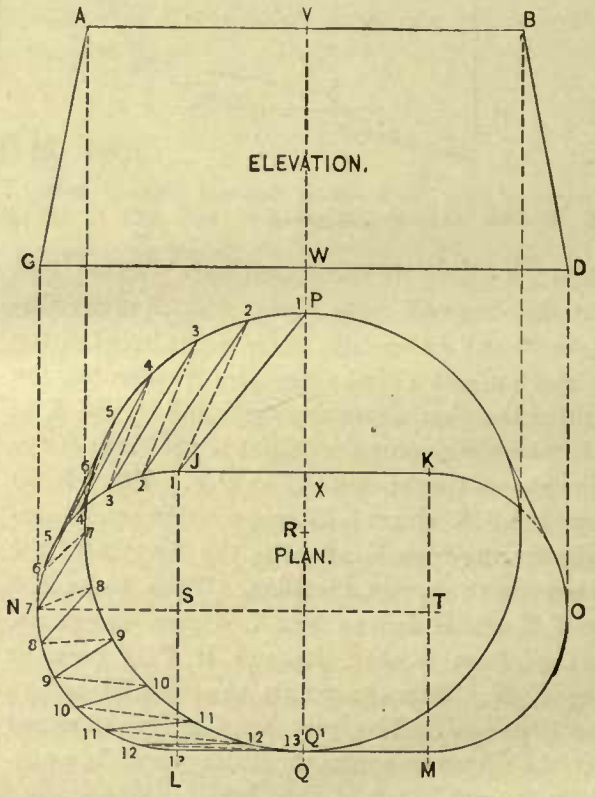


Fig. 607.—Plan and Elevation of Transition Piece—First Case.

N P O Q represents a plan of the shape described, above which A B D C shows an elevation of the front of the same, or as seen when looking toward Q, while to the left is shown a view obtained by looking toward the side N, in which E G corresponds to P X of the plan and F H to Q' Q.

Divide one-half of the plan of the top or round portion of the article into any convenient number of equal spaces, in this case 13. Since by the conditions of the problem one-half of the round end corresponds to the semicircular end of the oblong part, divide the semicircle J N L into the same number of equal parts.

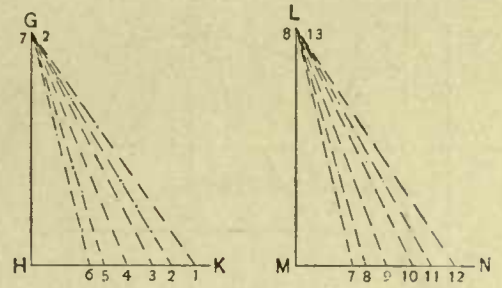


Fig. 609.—Diagrams of Triangles Based upon the Dotted Lines of the Plan, Fig. 607.

Then connect points in the two lines of the plan of the same numerals. For example, 1 with 1, 2 with 2, 3 with 3, etc. In like manner connect the points in the end of the oblong portion with points of the next higher number in the round end, as shown, as, for example, 1 with 2, 2 with 3, 3 with 4, etc. Upon all of these lines drawn in the plan it will be necessary to construct sections or triangles in which these lines form the bases and in which the vertical hight of the article W V is the altitude. The various hypothenuses thus obtained will then represent the true distances across the finished article upon the lines indicated in the plan. The triangles corresponding to the solid lines of the plan are shown in Fig. 608, while those corresponding to the dotted lines of the plan are shown in Fig. 609. In order to avoid confusion each of these sets has been divided into two groups, as shown, and are constructed as follows: Lay off at any convenient place the line A B (Fig. 608), equal to V W of Fig. 607. From the point B, and at right angles to A B, draw the line B C and upon it set off the lengths of the several solid lines connecting the two outlines in the plan. Thus make B 1 equal to the distance 1 1 or J P of the plan. B 2 is equal to the distance 2 2 of the plan, and B 3 is equal to the distance 3 3 of the plan, etc. As already explained, D E is a duplicate of A B, and E F is drawn at right angles. On E F the spaces E 10, E 11, E 12 and E 13 are set off, being equal respectively to 10 10, 11 11, etc., of the plan. From the points thus established in the base lines B C and E F draw lines to the apices A and D, thus completing the triangles. Then the hypothenuses A 1, A 2, A 3, etc., D 13, D 12, etc., correspond to the width of the pattern measured between points indicated by like figures in the plan.

In the same general manner construct the triangles shown in Fig. 609, which correspond to sections on the dotted lines across the plan. G H and L M of Fig. 609 correspond to the hight V W of the elevation. H K and M N are drawn at right angles to the perpendiculars, and on these base lines spaces are set off, measuring from H and M respectively, corresponding to the length of the dotted lines across the plan. Thus H 1 corresponds to 1 2 of the plan, and M 12 corresponds to 12 13 of the plan. From the points thus established in the base line lines are drawn to the apices G and L, thus completing the triangles. These hypothenuses are equal to the width of the pattern measured between points connected by the dotted lines in the plan. By the conditions of the problem, inasmuch as there are straight portions in the oblong end, there will be portions of the pattern that will correspond to triangles the bases of which are equivalent to the length of the straight portion in the plan and the hights of which are equal respectively to the distances E G and F H of the side view.

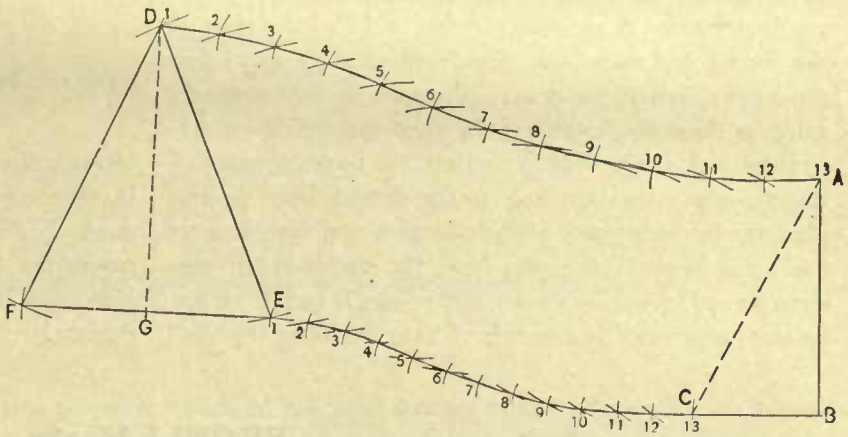


Fig. 610.—Pattern of Transition Piece Shown in Fig. 607.

Therefore, to describe the pattern proceed as follows: At any convenient place, as shown by A B in Fig. 610, draw a line equal to the width of the pattern at a point corresponding to Q' Q in the plan. This would be the same as F H of Fig. 607 or 611. To complete the triangular portion referred to set off from B the distance B C equivalent to Q L of Fig. 607, thus obtaining the point C. The dotted line A C in the pattern is drawn to show the portion obtained by this means. From C as center, with the space 13 12 of the plan of the oblong end as radius, describe a small arc, as shown to the left. Then from A as center, with radius L 12 of Fig. 609, corresponding to the width of the pattern measured on the dotted line 13 12 of the plan, describe another arc intersecting the one just drawn, thus establishing the point 12 in the lower edge of the pattern. From 12 as center, with D 12 of Fig. 608 as radius, being the width of the pattern on the line 12 12 of the plan, describe a short arc, as shown at 12 in the upper line in the pattern. Intersect this with another arc drawn from A as center, with 13 12 of the plan of the round end as radius, thus locating the point 12 in the upper line of the plan. Proceed in this manner, using in the order described the stretchout of the semicircular end of the oblong section, the hypothenuses of the triangles corresponding to the dotted lines in the plan, the hypothenuses of the triangles corresponding to the solid lines in the plan and the stretchout of the circular end, reaching finally the points D and E of the pattern, representing one side of the remaining triangular section to be added. From E as center, with K J of the plan as radius, describe an arc. From D as center, with radius equal to D E of the pattern, strike a second arc intersecting the one just drawn, thus locating the point F. Connect F and E and also F and D, thus completing the pattern of the part corresponding to K J P of the plan. The dotted line D G drawn across the pattern corresponds to the line X P of the plan, and D A B G will be one half of the finished pattern.

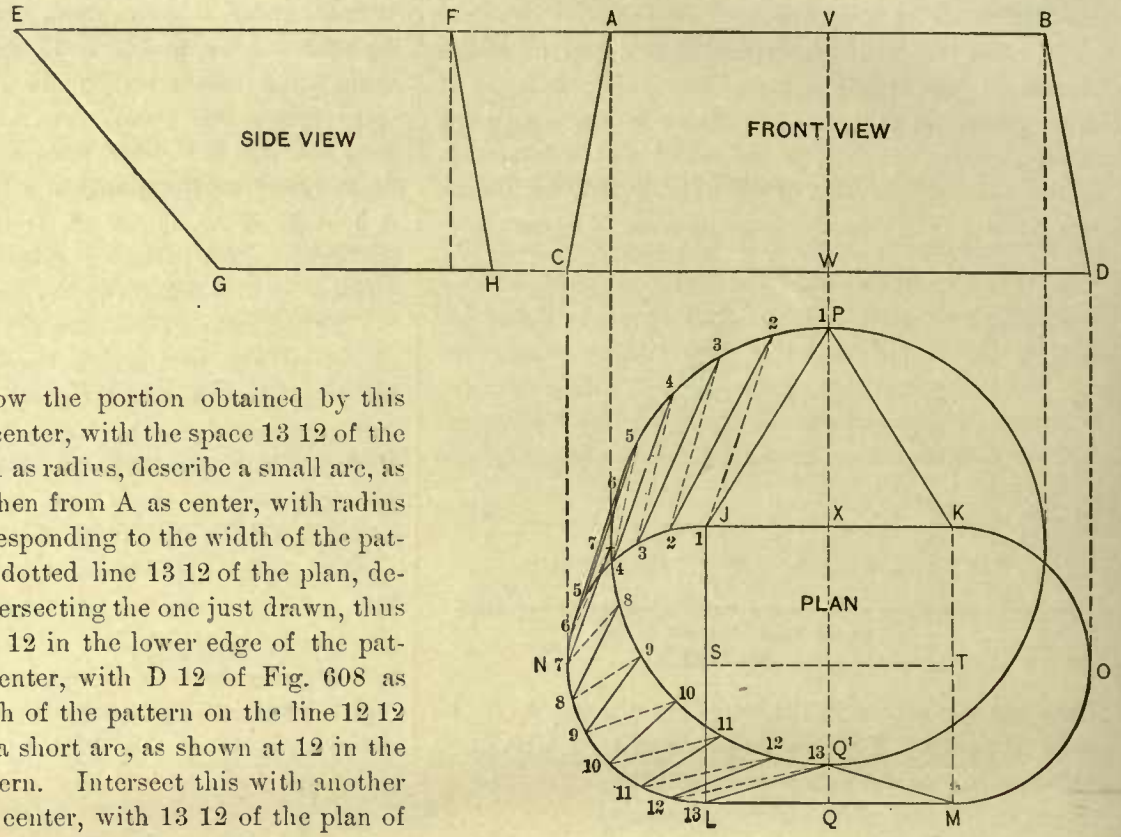


Fig. 611.—Plan and Elevation of Transition Piece—Second Case.

PROBLEM 189.

Pattern for an Offset Between Two Pipes, Oblong in Section, whose Long Diameters Lie at Right Angles to Each Other.

In Fig. 612 are shown the plan and elevations of an offset or transition piece to form a connection between two pipes of oblong profile which will be spoken of in the demonstration as the *upper* and the *lower* pipes. M N O P Q L of the plan is the section or profile of the upper pipe which begins at the line A B of the elevation and extends upward, while F G H I J K of the plan is the section of lower pipe which begins at the line D C of the elevation and extends downward, A B C D being one view of the offset. At

the right the same plan is shown turned one-quarter way around, from which, and the front elevation, are projected a side elevation of the offset. Corresponding points in the two plans are indicated by the same letters, capitals being used in the one and italics in the other.

An inspection of the plan will show that the long diameter O L of the upper pipe cuts the profile of the lower pipe nearer one end than the other, from which it must be concluded that the pattern cannot be composed of symmetrical halves or quarters and that therefore the entire pattern must be developed at one operation.

As the sections of both pipes may be said to consist of four quarter circles joined to the straight side, the pattern will consist principally of four rounded corners joining the quarter circles which occupy the same relative position in the two pipes. Thus lines joining the quarter circles F G of the bottom and L M of the top would form one corner of the envelope of the offset. Lines from G H of the bottom to N O of the top would form another corner, lines from I J up to O P a third corner and lines from J K up to Q L the fourth. Lying between these corner pieces are the two triangular end pieces K L F and I H O and the side pieces M N G and Q P J. For convenience in describing the pattern the joint will be assumed through one of the ends at the line E L.

Preparatory to obtaining the pattern, first divide

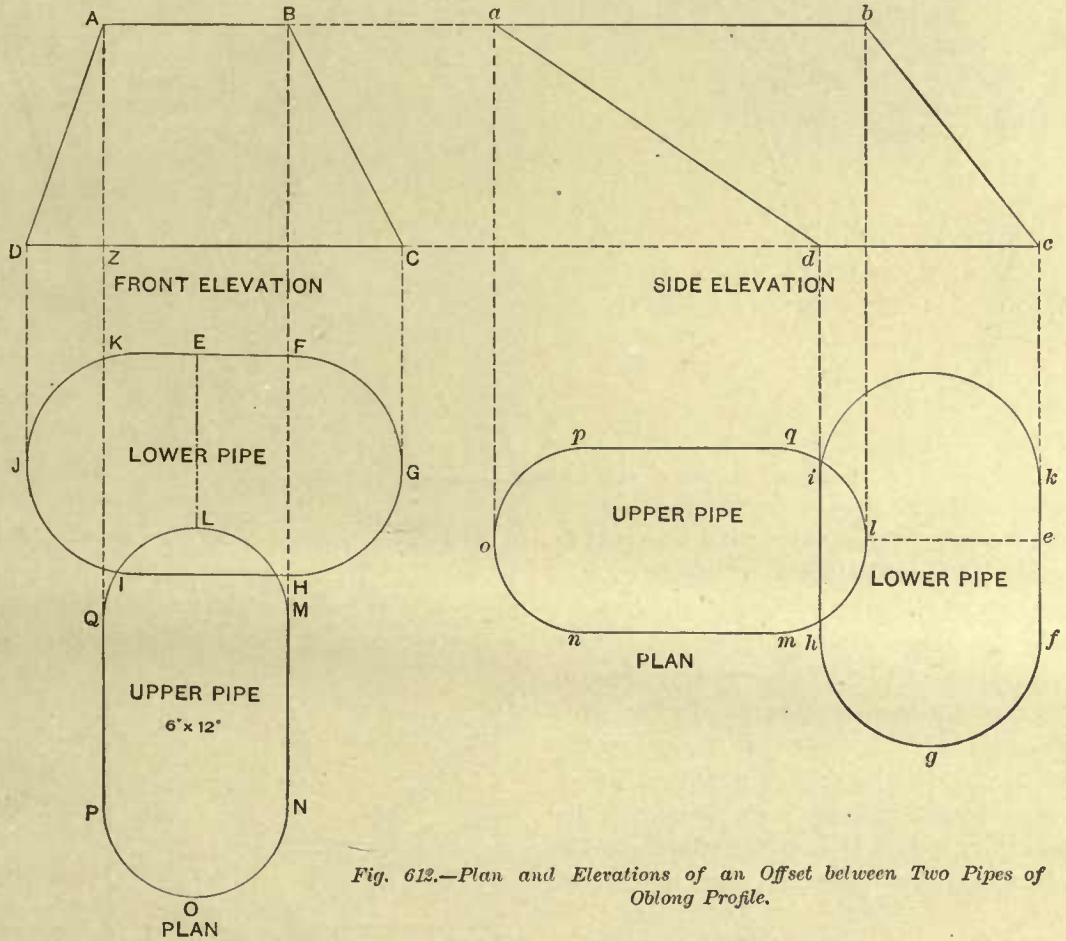


Fig. 612.—Plan and Elevations of an Offset between Two Pipes of Oblong Profile.

each of the four quarter circles of the lower pipe into the same number of equal parts; also divide the profile of the upper pipe in the same manner. To avoid confusion of lines two separate plans are shown in Figs. 613 and 614 for obtaining these divisions. In Fig. 613 are shown the divisions of what may be called the back end, while Fig. 614 shows those of the front end. As will be seen by these plans, the points have been numbered alternately in the bottom and the top. Solid lines are first drawn, as shown, connecting points 1 2, 3 4, 5 6, etc., after which the four-sided figures thus

produced are divided diagonally by the dotted lines 1 4, 3 6, 5 8, etc.

The next operation is the construction of a series of right angled triangles whose bases shall be equal to the several solid and dotted lines which have just been drawn, and whose altitudes shall equal the straight hight of the offset. These have been arranged in four groups, shown in Figs. 615 to 618, corresponding to the four corner pieces above mentioned. In Fig. 615, draw the right angle R S T, making R S equal to the straight hight of the article, as indicated by A Z of front elevation. Measuring from S, set off on S T the lengths of solid lines in F G M L of the plan Fig. 613, including L E, which will give the slant hight corresponding with *b c* of the side elevation. Connect the points in S T with R, as shown by the solid lines. These hypothenuses represent the distances from points between F and G in the lower pipe to points between M and L of upper pipe, as indicated by the solid lines in plan. For the diagram of triangles representing the

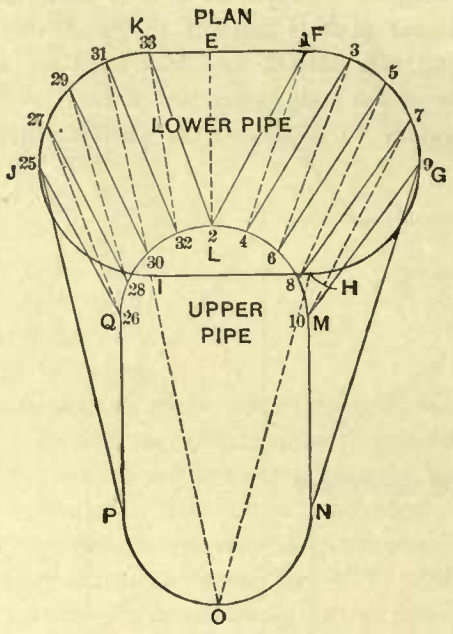


Fig. 613.

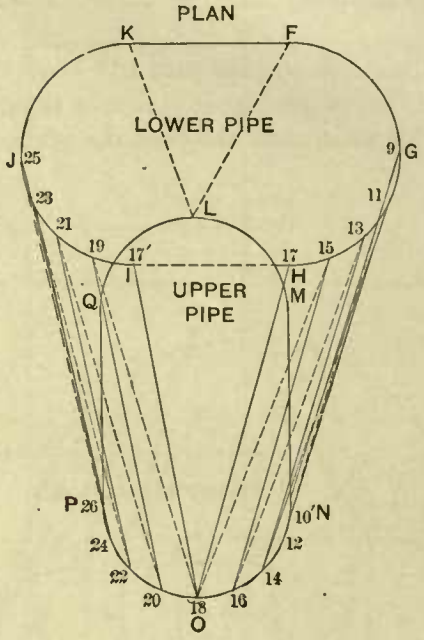


Fig. 614.

Duplicates of Plan in Fig. 612, Showing System of Triangulation.

dotted lines in F G M L of the plan, draw the right angle R' S' T', as shown at the right in Fig. 615, making R' S' equal to the straight hight of the article, as derived from A Z of front elevation. Measuring in each instance from S', set off on S' T' the lengths of dotted lines in F G M L, and from the points thus obtained draw lines to R'. The diagrams shown in Fig. 616 are constructed in the same manner and correspond to the solid and dotted lines in the corner G H O N, shown in Fig. 614. The diagrams of triangles in Fig. 617 are derived from the solid and dotted lines in I J P O of Fig.

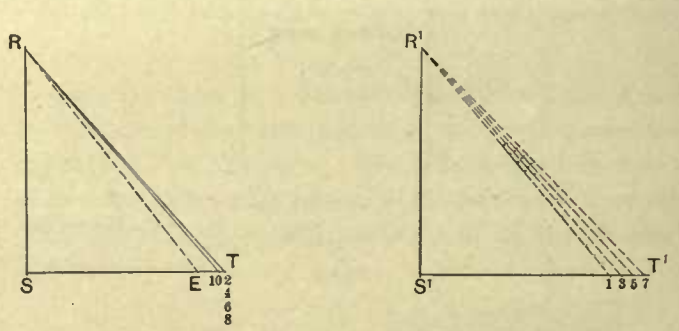


Fig. 615.—Diagrams of Triangles in F G M L of Fig. 613.

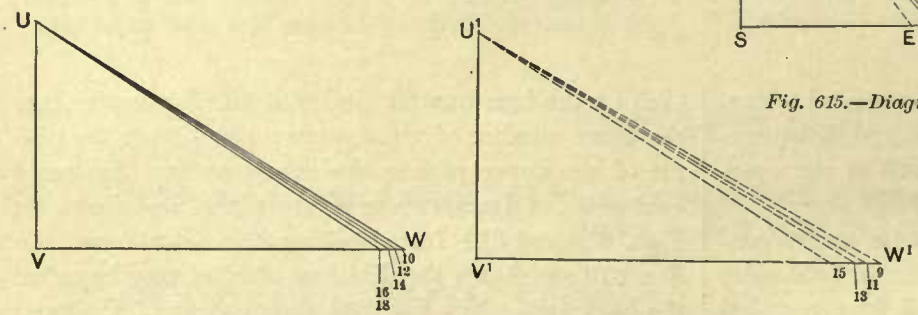


Fig. 616.—Diagrams of Triangles in G H O N of Fig. 614.

614, and in Fig. 618 are shown the diagrams of triangles derived from the solid and dotted lines in Q L K J of Fig. 613.

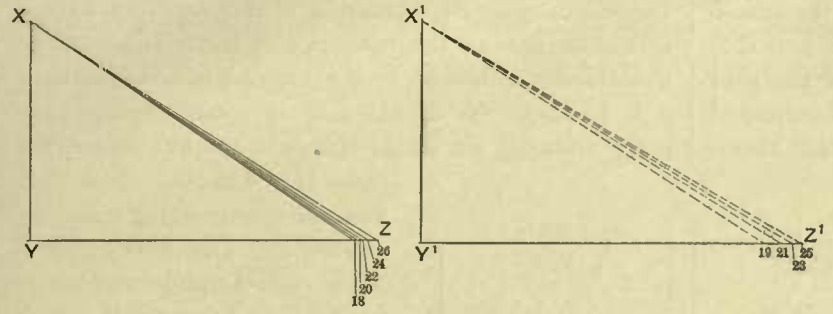


Fig. 617.—Diagrams of Triangles in I J P O of Fig. 614.

To develop the pattern draw any line, as E L of Fig. 619, in length equal to R E of Fig. 615, which gives the actual distance from E in the base to L in the top, as also shown by *b c* of side elevation and indicated in corresponding plan by *l e*. With E of pattern as center, and E F of plan as radius, strike a small arc, F, which intersect with one struck from L of pattern as center, and R T of Fig. 615 as radius, thus establishing point F of pattern. With point F of pattern as center, and R¹ 1 of Fig. 615 as radius, strike a small arc, 4, which intersect with one struck from point L of pattern as center, and L 4 of Fig. 613 as radius, thus establishing point 4 of pattern. With point 4 of pattern as center, and R 4 of Fig. 615 as radius, strike a small arc, 3, which intersect with one struck from point F of pattern as center, and F 3 of the plan as radius, thus establishing point 3 of pattern. Proceed in this manner, as above described, and as indicated by the solid and dotted lines, until the points G and M of pattern are located. With M of pattern as center, and M N of the plan as radius, strike a small arc, N, which intersect with one struck from G of pattern as center, and U W of Fig. 616 as radius, thus establishing point N of pattern. Proceed in the manner indicated until the remaining points in the pattern are located. It will be observed that the letters and figures in pattern designate points similarly indicated in Figs. 613 and 614. Lines traced through the points obtained as directed, and as shown from E to E′ and L′ to L, will produce the desired pattern.

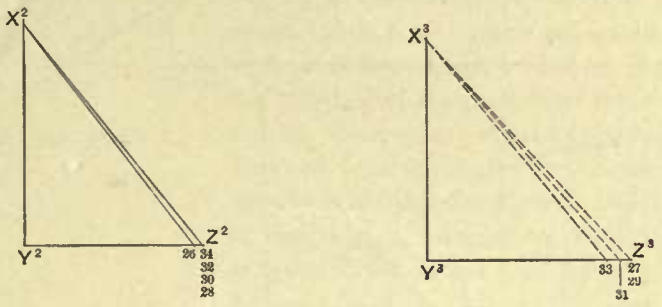
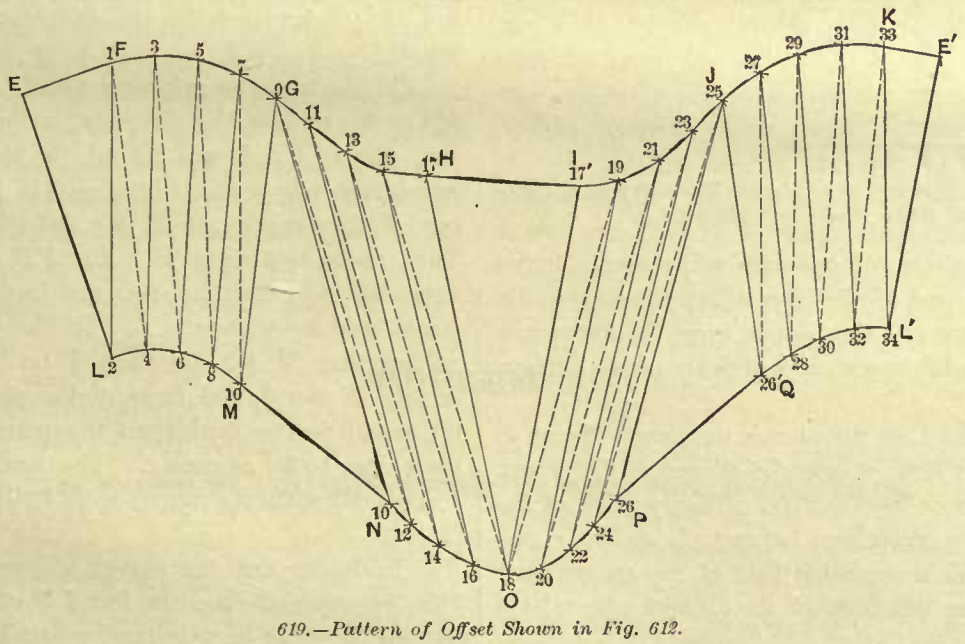


Fig. 618.—Diagrams of Triangles in Q L K J of Fig. 613.



619.—Pattern of Offset Shown in Fig. 612.

PROBLEM 190.

Pattern for an Irregular Flaring Article Whose Top is a Circle and Whose Base is a Quadrant.

In Fig. 620 G E F shows the plan of the article at the base, L J K the plan at the top and A B C D an elevation of one side. An inspection of the plan will show that the article consists of two symmetrical halves when divided by the line G H, and that, therefore, the triangulation of one-half will answer for the whole. On account of the dissimilarity between the outlines of the top and the bottom some judgment will be required in adopting a good division of the surface into triangles.

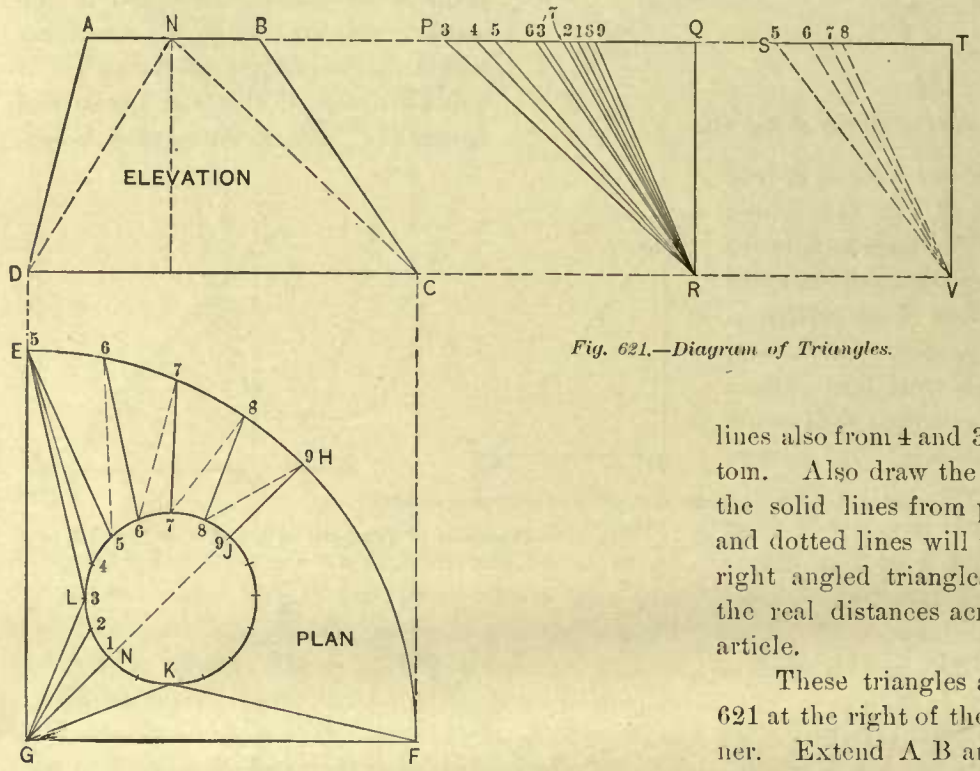


Fig. 620.—Plan and Elevation of an Article Whose Top is a Circle and Whose Base is a Quadrant.

As the point L of the plan is the nearest point to the adjacent side E G, it must be chosen as the vertex of a triangle whose base is E G. That portion of the circle of the top, therefore, between L and its corresponding point K in the other half of the article must be considered as the base of an oblique cone whose apex is at G.

It is always advisable in the division of a surface into triangles that the solid and dotted lines crossing the plan should intersect the outlines of the top and the bottom as nearly at right angles as possible. Therefore, since the remainder of the top (L to J) and E H of the base are the bases of a surface which must be so divided as to best serve the purposes of triangulation, it is advisable to divide L J into more spaces than E H, allowing the extra spaces in the top nearest the point L to form the bases of a number of converging triangles, as shown. Thus first divide E H into any suitable number of spaces, as shown by the small figures 5 to 9, then divide L J into a greater number of equal spaces than E H, as shown by the small figures 3 to 9. Connect points of like number in the two outlines by solid lines, commencing at H and J, as shown from 9 9 to 5 5, drawing lines also from 4 and 3 of the top to 5 (E) of the bottom. Also draw the dotted lines 5 6, 6 7, etc., and the solid lines from points in L N to G. These solid and dotted lines will then form the bases of a series of right angled triangles whose hypothenuses will give the real distances across the envelope of the finished article.

Fig. 621.—Diagram of Triangles.

These triangles are constructed, as shown in Fig. 621 at the right of the elevation, in the following manner. Extend A B and D C of the elevation, through which draw any vertical line, as Q R. From Q on Q P set off the lengths of all the solid lines of the plan. Thus make Q 9 equal to 9 9 or J H of the plan, Q 8 equal to 8 8 of the plan, etc., and from the points thus established draw lines to R. In like manner draw the vertical line T V, and from T on T S set off the lengths of the dotted lines of the plan, as shown by the small figures, and from the points thus obtained draw lines to V, as shown. The small figures in S T correspond with the figures in L J, the top line of the plan.

In laying out the pattern shown in Fig. 622 the joint is assumed upon the line J H of the plan. The pattern may be best begun by first laying out one of the large triangles forming a side of the article, as E L G or G K F of the plan, shown also by D N C of the elevation, Fig. 620. Draw any horizontal line, as E G of Fig. 622, equal in length to E G of the plan.

From E as center, with radius R 3 of Fig. 621, describe a small arc near L, which intersect with another arc drawn from G as center, with a radius equal to R 3′ of Fig. 621, thus establishing the point L of the pattern. From G of the pattern as center, with radii equal to R 2 and R 1 of Fig. 621, describe small arcs, as shown between L and K of the pattern. Take between the points of the dividers a space equal that used in dividing the arc L K of the plan, and placing one foot of the dividers at L of the pattern step from arc to arc, reaching K, as shown, and through the points thus obtained draw L K of the pattern; also draw K G. From E of the pattern as center, with radii equal to R 4 and R 5 of Fig. 621, describe small arcs to the left of L. With the dividers set to the space used in dividing the arc L J of the plan, place one foot at L (3) and step first to arc 4, then to arc 5, thus establishing the points 4 and 5.

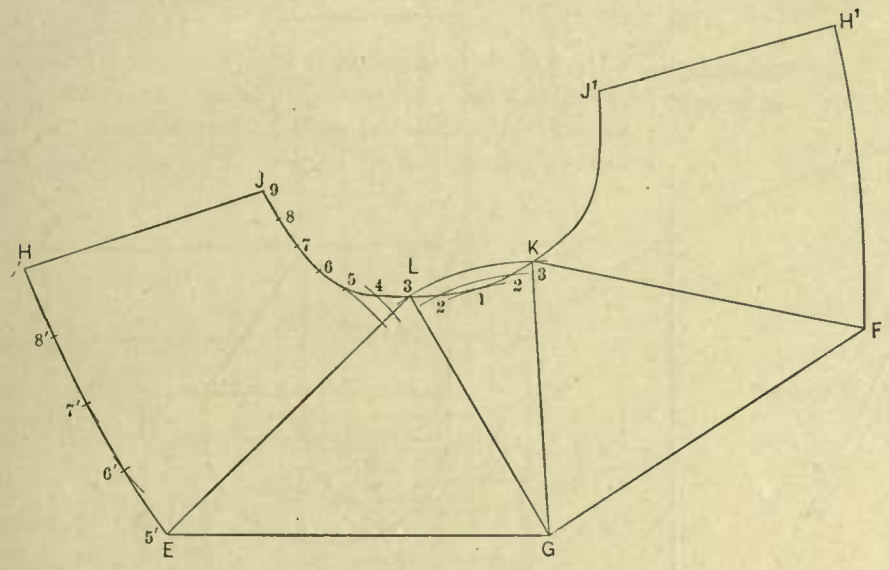


Fig. 622.—Pattern of Article Shown in Fig. 620.

With the last obtained point, 5, of the pattern as center, and a radius equal to the dotted line V 5 of Fig. 621, describe a small arc (6′), which intersect with another arc struck from point E of pattern as center, with a radius equal to 5 6 of the base line E H of the plan, thus establishing the point 6′ of the pattern. With 6′ of the pattern as center, and a radius equal to R 5 of Fig. 621, describe a small arc (6), which intersect with another arc struck from 5 of pattern as center, with a radius equal to 5 6 of the top line L J of the plan, thus establishing the point 6 of the pattern. Proceed in this manner in the construction of the remaining triangles of the pattern, using alternately the lengths of the dotted and the solid hypothenuses in Fig. 621 corresponding to the dotted and the solid lines crossing the plan, in the order in which they occur, to determine the width of the pattern; the spaces in E H of the plan to form the lower line E H of the pattern and the spaces in L J of the plan to form the upper line of the pattern, all as shown. The remaining parts of the pattern can be obtained by any convenient means of duplication, K F G being a duplicate of L E G and K J′ H′ F being a duplicate of L J H E.

PROBLEM 191.

The Patterns for a Three-Piece Elbow, the Middle Piece of which Tapers.

In Fig. 623, let A B D F H G E C be the side view of a three-piece elbow, the middle piece (C D F E) of which is made tapering. The piece C D F E may also be described as an offset between two round pipes of different diameters. A half profile of the upper and smaller of the two pipes is shown by *a m b*, while *g n h* shows that of the larger pipe. The straight portions A B D C and E F H G are in all respects similar to many pieces whose patterns have already been described in the first section of this chapter in Problems 38 to 45 inclusive. It will therefore be unnecessary to repeat the description in this connection.

Since an oblique section through a cylinder is an ellipse, an inspection of the drawing will show that the sections C D and E F, the upper and lower bases of the middle piece, must be elliptical. The first operation, therefore, will be to develop the ellipses, which may be done in the following manner: Divide the

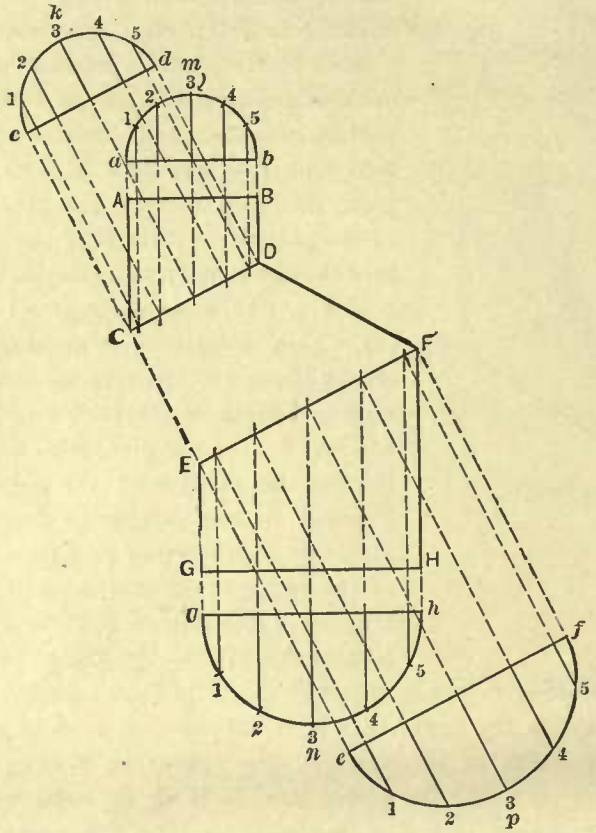


Fig. 623.—Elevation of a Three-Piece Elbow, the Middle Piece of which Tapers.

profile *a m b* into any convenient number of equal spaces, as shown by the small figures. From the points thus obtained drop lines vertically to *a b* and continue them till they cut the line C D. From the intersections on C D carry lines at right angles to the same indefinitely, as shown. Through these lines draw any line, as *c d*, parallel to C D. Upon each of the lines drawn from C D, and measuring from *c d*, set off the lengths of lines of corresponding number in the profile *a m b*, measuring from *a b*. A line traced through the points thus obtained, as shown by *c k d*, will be the required elliptical section. The section upon the line E F may be obtained in the same manner, all as shown by *e p f*.

In Fig. 624, C D F E is a duplicate of the middle piece of Fig. 623, below which is drawn its half plan made up of the elliptical sections just obtained, all as shown by corresponding letters. The piece thus be-

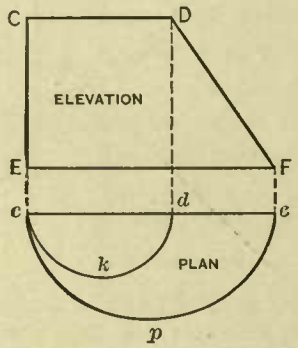


Fig. 624.—The Middle Piece of Elbow in Fig. 623, with Plans of its Bases Arranged for Triangulation.

comes an irregular flaring article or transition piece, the envelope or pattern of which may be obtained in exactly the same manner as described in Problems 184 or 186, to which the reader is referred. The elevation in Fig. 623 is so drawn that C D and E F are parallel, and C E is at right angles to both. Should the elevation, however, be so drawn that C D is not parallel with E F the conditions will then become the same as in Problem 193 succeeding, which see; and should C E be drawn otherwise than vertically, the plan would then resemble that shown in Problem 194.

PROBLEM 192.

The Patterns for a Raking Bracket in a Curved Pediment.

In Fig. 625, let C E F D be the front elevation of a portion of a curved pediment whose center is at K, and of which E K is the center line. C A B D of the same elevation represents the face view of a bracket having vertical sides, of which E G F is the normal profile. Since the bracket sides are vertical and are necessarily at different distances from the center line, it will be easily seen that they are of different lengths or hights; that is, the side C D, being further from E K than the side A B, is longer. The patterns for

the two sides will therefore be different and the face piece will be really an irregular flaring piece.

It will first be necessary to obtain the pattern or profiles of the two sides. To facilitate this operation the normal profile of the bracket E G F has been so placed that its vertical line or back coincides with the center line E K of the arch. Divide the face of this profile into any convenient number of parts, as shown by the small figures, and from these points carry lines at right angles to the back of the bracket, cutting the line E F, as shown. Thence carry lines around the arch from the center K, from which the same is struck, cutting the sides A B and C D. Conveniently near the lower side of the bracket draw any vertical line, as E' B', as a base line upon which to construct the true sides of the bracket. At any convenient position upon this line, above or below, as at G' E' F', draw a duplicate of the normal profile, so that its back or vertical line shall coincide with E' B', and divide its face line into the same spaces as G F. Place the

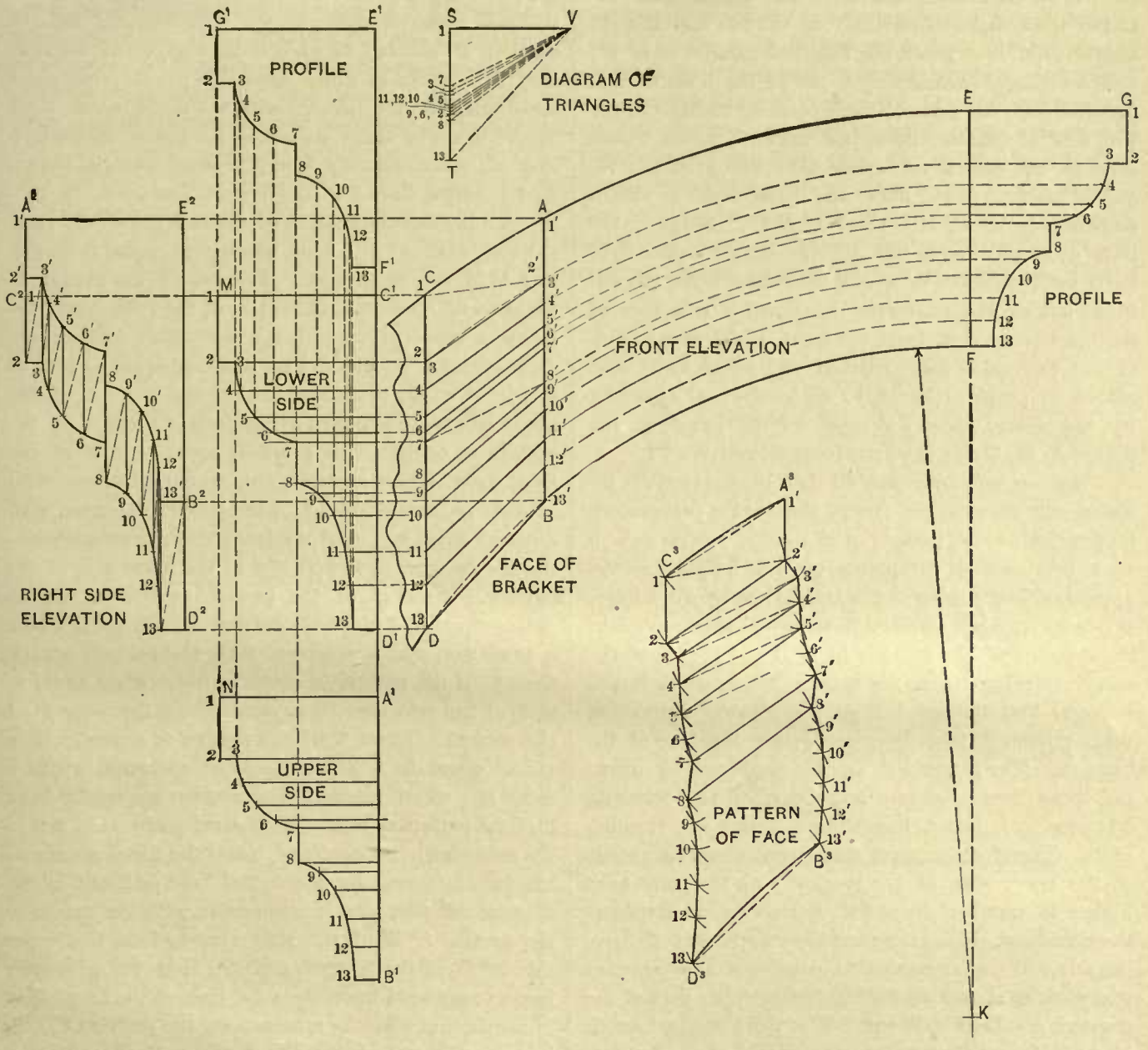


Fig. 625.—A Raking Bracket in a Curved Pediment, Showing the Patterns for Its Face and Sides.

T-square at right angles to the line E' B', and, bringing it successively against the points in the side C D, draw lines cutting E' B', continuing the same indefinitely to the left, as shown. At any convenient position, as A' B', on the line E' B' transfer the spaces from A B, as shown, and from the points thus obtained draw lines indefinitely to the left also at right angles to E' B'. Place the T-square parallel to E' B', and, bringing it successively to the points in the normal profile G' F', cut lines of corresponding number in the two sets of parallel lines just drawn. Lines traced through the points of intersection will give the required patterns of the lower and upper sides, as shown respectively by C' M D' and A' N B'. Some of the lines of projection in the pattern of the upper side have been omitted to avoid confusion. At the extreme left of the engraving is shown a side view of the bracket as seen from the right, which is made up of the two sides just obtained and which have been placed in proper relation to each other, all as shown by the dotted lines projected to the left from the points A, B, C and D of the front elevation.

Having now obtained all that is necessary, it remains to triangulate the face of the bracket preparatory to developing the pattern of the same. With this in view first connect all points of like number in the upper and lower sides of the front view by solid lines, as shown. Also connect them in the side elevation. Since points of like number in A B and C D have the same projection from the back of the bracket, it will be seen that the solid lines just drawn connecting them represent true distances across the face of the bracket. The four-sided figures produced by drawing these lines must now be subdivided into triangles by means of dotted lines drawn diagonally through each. Therefore connect each point upon the profile of the lower side of the bracket with the point next higher in number upon the upper side, as shown in the side view. To determine the true length of these lines it will be necessary to construct a diagram of triangles, as shown by S V T in the upper part of the engraving. Draw S V and S T at right angles to each other. Make S V equal to the width of the bracket measured horizontally across the face, and upon S T, measuring from S, set off the lengths of the several dotted lines in the side view, as shown by the small figures. From each of points in S T draw lines to V. Then these lines will be the real distances between points of corresponding number on the lower side of the bracket and points of the next higher number upon the upper side. The figures in S T correspond with the figures upon the lower side of the bracket, the point V representing, in the case of each line, the next higher number; thus 2 V is the distance from 2 to 3′ across the face of the bracket, 3 V the distance 3 4′, 4 V the distance 4 5′, etc. The dotted lines in the side view representing the distances 1 2 and 7 8 cannot, of course, be shown in that view, because they lie in surfaces which appear in profile; but since these surfaces are parallel with the plane of the back of the bracket these distances for use in the pattern may be taken directly from the front view, as shown by the dotted lines 1 2′ and 7 8′ in that view.

To lay out the pattern of the face piece first draw any line, as C^3 A^3 or 1 1′ of the pattern, equal in length to 1 1′ of the front view. From C^3 of the pattern as center, with a radius equal to 1 2′ of the front view, describe a small arc, which intersect with another arc drawn from A^3 as center, with a radius equal to 1′ 2′ of the front view, thus establishing the point 2′ of the upper side of the pattern of the face. From 2′ of the pattern as center, with a radius equal to 2 2′ of the front view, strike a small arc, which intersect with another arc struck from 1 of the pattern as center, with a radius equal to 1 2 of the front view, thus establishing the position of the point 2 in the lower side of the pattern. From 2 of the pattern as center, with a radius equal to 2 V of the diagram of triangles, strike a small arc, which intersect with another arc struck from 2′ of the pattern of center, with a radius equal to 2′ 3′ of the side view, thus establishing the point 3′ of the pattern. From 3′ of the pattern as center, with a radius equal to 3 3′ of the front elevation, strike a small arc, which intersect with another arc struck from 2 of the pattern as center, with a radius equal to 2 3 of the side view. So continue, using the distances across the face indicated by the dotted lines as found in the diagram of triangles in connection with the spaces in the profile A^2 B^2 of the side view to form the upper side A^3 B^3 of the pattern, and the distances across the face as measured upon the solid lines of the front view in connection with the spaces upon the profile C^2 D^2 to form the lower side C^3 D^3 of the pattern, until the points 13 and 13′ are reached.

As the lines C A and D B of the front of the bracket must be cut to fit the curves of the moldings above and below, against which the bracket fits, the corresponding lines of the pattern can be drawn with radii respectively equal to K E and K F, as shown by the curved lines C^3 A^3 and D^3 B^3 of the pattern.

PROBLEM 193.

Pattern for a Transition Piece to Join Two Round Pipes of Unequal Diameter at an Angle.

In Fig. 626, D C K L shows a portion of the larger pipe, of which M P N O is the section; H G B A a portion of the smaller pipe, of which E J F I is the section; and A B C D the elevation of the transition piece necessary to form a connection between the two pipes at the angle H A L. The drawing also shows that the ends of the two pipes to be joined are square,

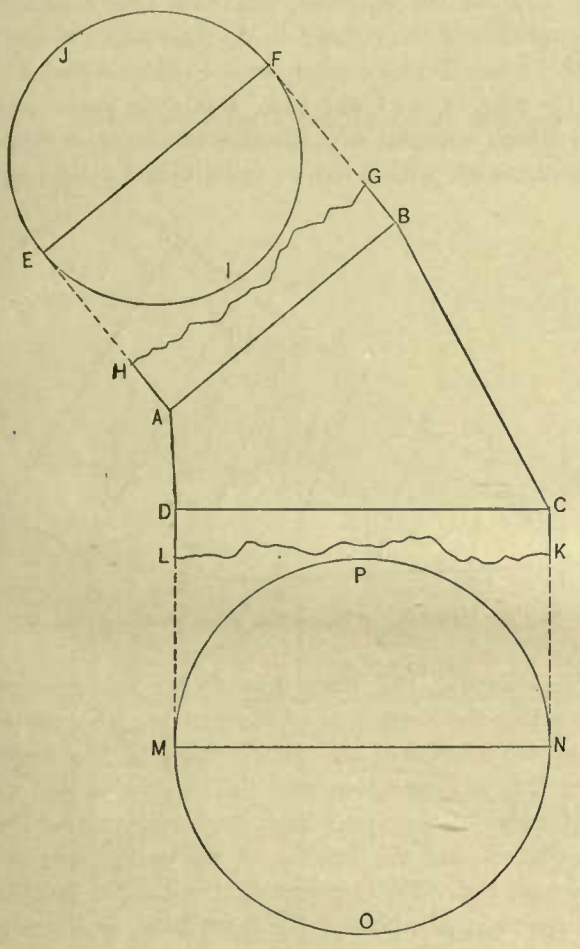


Fig. 626.—Elevation of a Transition Piece Joining Two Round Pipes of Unequal Diameter at an Angle.

or cut off at right angles, so that the lower base of A B C D is a perfect circle whose diameter is D C (or M N) and the upper base is a circle whose diameter is A B (or E F), and also that the side A D is vertical. In the choice of a method of dividing the surface of the piece A B C D into triangles, either the elevation or the plan can be made use of for that purpose, according to convenience. In the demonstration here given the elevation has been used by way of variety, all as shown in Fig. 627. Proceed then to divide the plan of the upper base into any convenient number of equal spaces, as shown, and drop a line from each point at right angles to A B, cutting A B, and numbering each point to correspond with the number upon the plan. In like manner divide the plan of the lower base into the same number of equal spaces, and erect a perpendicular line from each, cutting the line D C, and numbering the points of intersection in the same order, or to correspond with the points in the upper base, all as shown. Connect the points in D C with points of similar number in A B by solid lines, also

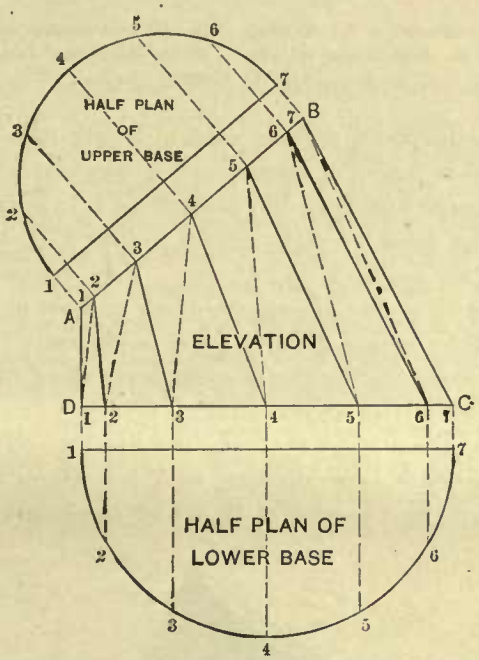


Fig. 627.—Triangulation of Transition Piece Shown in Fig. 626.

connect points in D C with points of the next higher number in A B by dotted lines, which will result in a triangulation suitable for the purpose.

The next step will be to construct sections through the piece upon all of the lines upon the elevation (both solid and dotted), which operations are shown in Figs. 628 and 629, and which may be done in the following manner: Upon any horizontal line, as T S of Fig. 628, erect a perpendicular, as T U. Upon T S set off from T the several distances of the points in the lower base from the center line 1 7 of the plan, as measured upon the vertical lines (Fig. 627), all as indicated by the small figures. Upon T U set off the lengths of the

solid lines of the elevation, numbering each point thus obtained to correspond with its line in the elevation. From each of the points upon T U draw horizontal

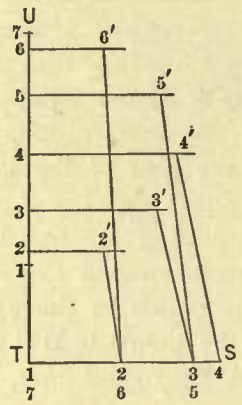


Fig. 628.—Diagram of Sections Taken on Solid Lines of Fig. 627.

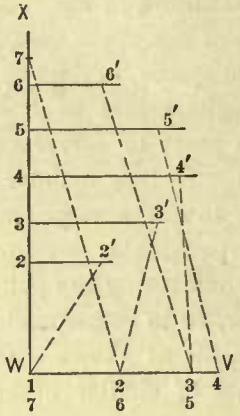


Fig. 629.—Diagram of Sections Taken on Dotted Lines of Fig. 627.

lines to the right, making each in length equal to the distance of points of corresponding number in the plan of the upper base from the center line 1 7, as measured upon the lines at right angles to line A B, thus obtaining the points 2′, 3′, 4′, etc. Now connect these points with points of corresponding number in the base line T S by means of solid lines, as shown.

In constructing the sections upon the dotted lines of the elevation, shown in Fig. 629, the same course is to be pursued as that employed in Fig. 628. The base line W V is a duplicate of T S. Upon the perpendicular line erected at W set off the lengths of the

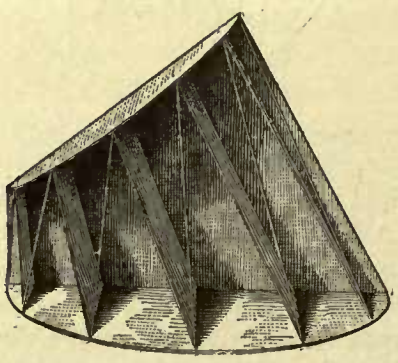


Fig. 631.—Perspective View of Model.

several dotted lines of the elevation, numbering each point thus obtained to correspond with the number at the top of its line in the elevation. From each point draw a horizontal line to the right as before, which make equal in length to the similar lines in Fig. 628, numbering each point as shown by the small figures 2′, 3′, 4′, etc. Now connect each of these points with the point of next lower number in the base line V W by a dotted line.

Having obtained all the necessary measurements, the pattern for one-half the envelope of A B C D may be developed in the following manner: Draw any line, as A D in Fig. 630, which make equal in length to A D of the elevation. With A as a center, and a radius equal to 1 2 of the plan of the upper base, Fig. 627, strike a small arc, which intersect with another struck from D as a center, with a radius equal to the dotted line 1 2′ of the diagram, Fig. 629, thus establishing the position of the point 2 in the upper line of the pattern. From D as a center, with a radius equal to 1 2 of the plan of the lower base, Fig. 627, strike a small arc, which intersect with another struck from point 2, just obtained, with a radius equal to the solid line 2 2′

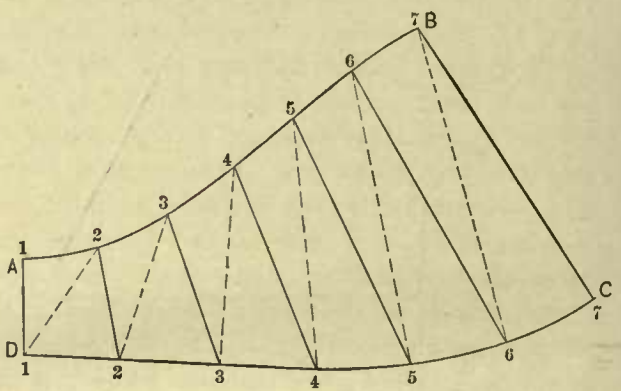


Fig. 630.—Pattern of Transition Piece Shown in Fig. 627.

of the diagram, Fig. 628, thus fixing the position of point 2 in the lower line of the pattern. So continue, using the lengths of the dotted lines in the diagram, Fig. 629, in connection with the lengths of the spaces in the plan of the upper base, to develop upper line of the pattern, and the lengths of the solid lines in the diagram, Fig. 628, in connection with the lengths of the spaces in the plan of the lower base, to develop the lower line of the pattern, using each combination alternately until the pattern is complete. As each new point of the pattern is determined it should be numbered, and the solid or dotted line used in obtaining the same may be drawn across the pattern if desired, merely as a means of noting progress, but these lines are not necessary, as each point is simply used as a center from which to find the next point beyond.

Sometimes, in order to more thoroughly understand the method employed in such an operation as the foregoing, it is desirable to construct a small model,

which can be made from cardboard or thin metal, the details of which are clearly shown in Fig. 631. The pieces forming the upper and lower bases of it should be duplicates of the half plans of the upper and lower bases shown in Fig. 627, having the lines there shown drawn upon them, and the piece forming the back is a duplicate of the plane figure A B C D. These three parts may be cut in one piece, after which a right angle bend on the lines A B and C D will bring the two bases into correct relative position. Five quadrilateral figures corresponding to those shown in Fig. 628 may now be cut and fastened in position, according to their numbers, between the two bases of the model. Threads or wires can be so placed as to correspond in position with the dotted lines shown in the elevation, Fig. 627, to complete the model. The model is only useful before the pattern is developed to assist in showing the shapes and order or rotation of the various triangles; and one constructed to the dimensions of any problem which may occur to the student at the outset of his study of triangulation will serve to assist his imagination in all subsequent operations.

PROBLEM 194.

The Pattern for a Flaring Collar the Top and Bottom of which are Round and Placed Obliquely to Each Other.

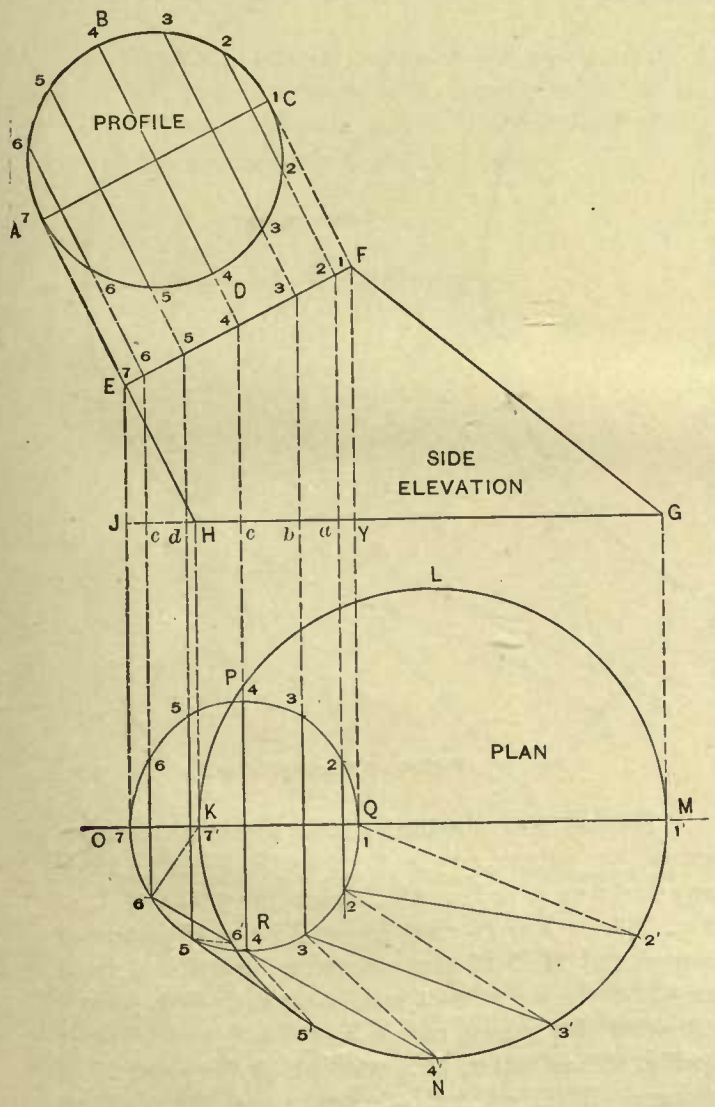


Fig. 632.—Plan and Elevation of Flaring Collar.

In Fig. 632 E F G H shows the side elevation of a flaring collar, the profile of the small end or top being shown at A B C D, and that of the bottom at K L M N of the plan. The conditions embodied in this problem are in no respect different from those of the problem immediately preceding. A slight difference in detail consists in the fact that in the former case the short side was at right angles to the larger end, while in the present case it is at right angles to the smaller end, but the pattern may be obtained by exactly the same method as that employed in the previous problem. However, as the elevation was there made use of to determine the triangulation, the plan will here be used upon which to determine the position of the triangles of which the pattern will subsequently be constructed.

Divide A B C of the profile into any convenient number of parts, and, with the T-square at right angles to E F of the elevation, carry lines from the points in A B C, cutting E F, as shown. Extend the base line G H to the left indefinitely, and through the center of plan of base draw O M, parallel with H G of elevation. Drop lines from the points in E F, extending them vertically through O M. With the dividers take the distance across the profile A B C D on each of the several lines drawn through it, and set the same distance off on corresponding lines drawn through O M. That is, taking A C as the base of measurement in the one case, and O M in the other, set off on the latter, on each side, the same length as the several lines measure on each side of A C. Through the points thus obtained trace a line, as shown by O P Q R, thus obtain-

ing the shape of the upper outline as it would appear in the plan.

As both halves of the plan when divided by the line O M are exactly alike, it will only be necessary to use one-half in obtaining the pattern; therefore divide K N M of plan into the same number of parts as was the half of profile, in the present instance six, as shown by the small figures. Number the points in K N M to correspond with the points in O R Q, and connect corresponding points by solid lines, as shown by 1 1′, 2 2′, 3 3′, etc. Also connect the points in O R Q with those of the next higher number in K N M, as shown by the dotted lines 1 2′, 2 3′, 3 4′, etc. The solid and dotted lines thus drawn across the plan will represent the bases of a number of right angled triangles whose altitudes are equal to the vertical lines between E F and J Y of the elevation, and whose hypothenuses, when obtained, will give the real distances across the sides of the finished article in the direction indicated by the lines across the plan.

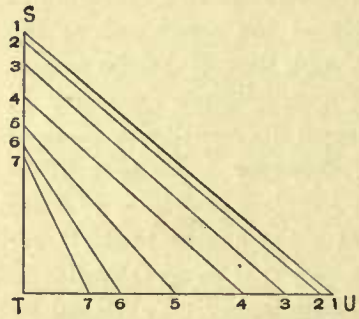


Fig. 633.—Diagram of Triangles Based upon the Solid Lines of the Plan in Fig. 632.

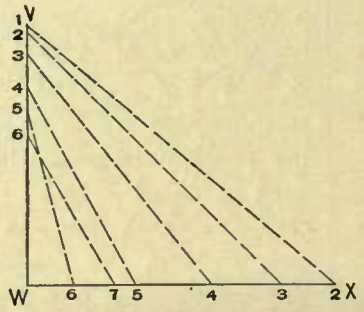


Fig. 634.—Diagram of Triangles Based upon the Dotted Lines of the Plan in Fig. 632.

To construct these triangles proceed as follows: Draw any right angle, as S T U in Fig. 633. On T U, measuring from T, set off the lengths of solid lines in plan, making T U of diagram equal to Q M of plan, T 2 of diagram equal to 2 2′ of plan, T 3 of diagram equal to 3 3′ of plan, etc. From T on T S set off the length of lines in E F Y J of elevation, making T S of diagram equal to F Y of elevation, T 2 of diagram equal to *a* 2 of elevation, T 3 of diagram equal to *b* 3 of elevation, etc. Connect points in T S with those of similar number in T U, as shown by the solid lines. The hypothenuses of the triangles thus obtained will give the distance from points in plan of base to points of similar number of top as if measured on the finished article. The diagram of triangles in Fig. 634 is constructed in a similar manner. Draw the right angle V W X and on W X set off the lengths of dotted lines in plan, and from W on W V the lengths of lines in E F Y J of elevation, excepting the line E J, or No. 7, which is not used. Connect the points in W V of diagram with those of the next higher number in W X, as shown by the dotted lines in diagram and by similar lines in the plan. The resulting hypothenuses will give the correct distances from points in top of article to points of next higher number in the plan of base.

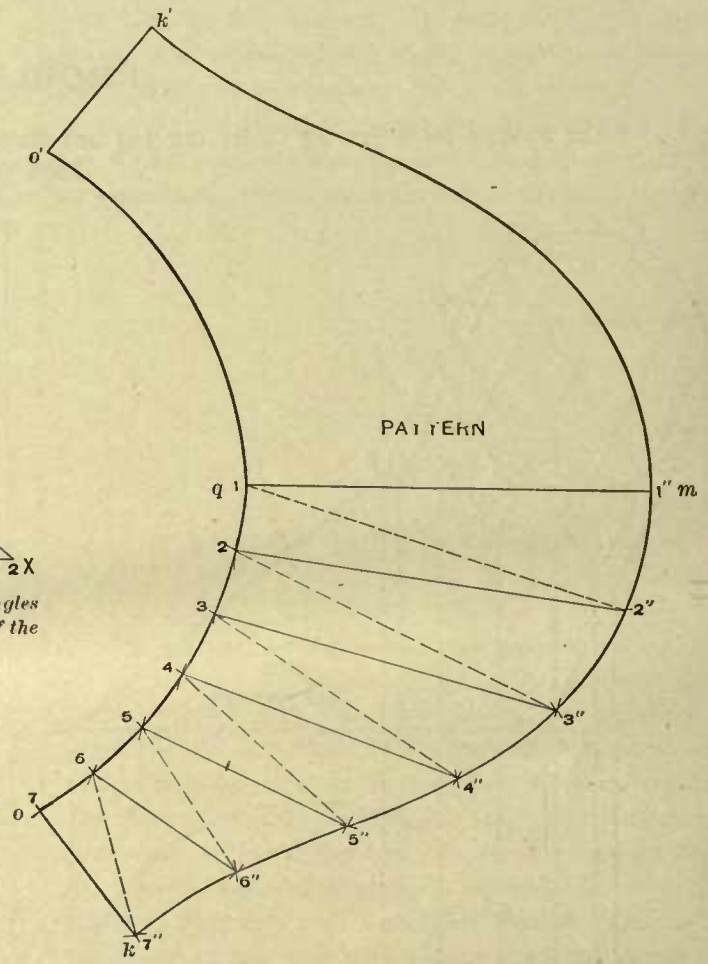


Fig. 635.—Pattern of Flaring Collar.

Having now obtained all the necessary measurements, the pattern may be developed as follows: Draw any line, as *q m* in Fig. 635, in length equal to S U of Fig. 633, or F G of elevation. With *m* of pattern as center, and M 2′ of plan as radius, describe a small arc (2″), which intersect with one struck from point *q* of pattern as center, and V X of diagram of triangles in Fig. 634 as radius, thus establishing the point 2″ of pattern. With point 2″ of pattern as center, and 2 2 of Fig. 633 as radius, describe a small arc (2), which

intersect with another struck from point q of pattern as center, and C 2 of profile as radius, thus establishing the point 2 of pattern. With 2 of pattern as center, and 2 3 of Fig. 634 as radius, describe a small arc (3″), which intersect with another struck from 2″ of pattern as center, and 2′ 3′ of plan as radius, thus establishing point 3″ of pattern. With 3″ of pattern as center, and 3 3 of Fig. 633 as radius, describe a small arc (3), which intersect with one struck from point 2 of pattern as center, and the distance 2 3 of profile as radius, thus establishing point 3 of the pattern. Proceed in this manner, using the hypothenuses of the triangles in Figs. 633 and 634 for the distances across the pattern; the distances between the points in the plan of base for the stretchout of the bottom of pattern; and the distances between the points in the profile of top for the stretchout of the top of pattern. Lines drawn through the points of intersection, as shown by $q\ o$ and $m\ k$, will, with $q\ m$ and $o\ k$, constitute the pattern for half the article. The other half of the pattern $q\ o'\ k'\ m$ can be obtained by any convenient means of duplication.

PROBLEM 195.

The Pattern for a Flaring Flange, Round at the Bottom, the Top to Fit a Round Pipe Passing through an Inclined Roof.

In Fig. 636, let K L represent the pitch of the roof, A B C D the elevation of the flaring flange, A J D the half plan of the base, and B E C the half plan of round top through which the pipe passes.

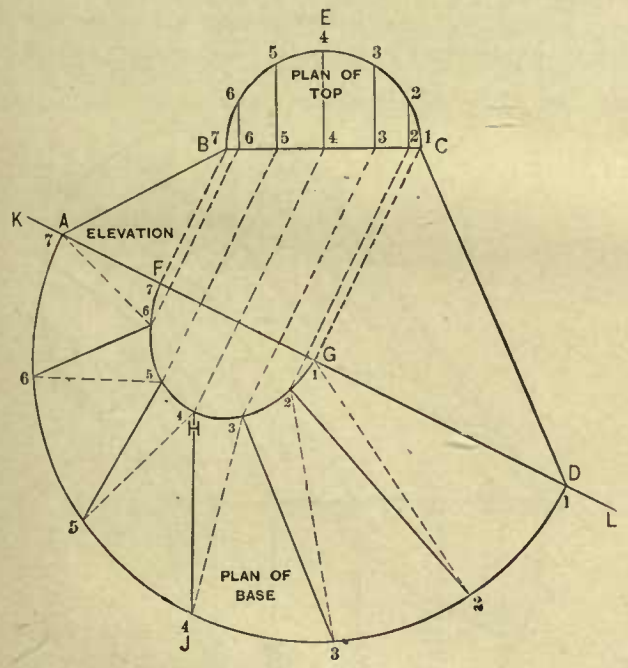


Fig. 636.—Elevation of a Flaring Flange to Fit Against an Inclined Roof.

It will be seen by comparison that this problem embodies exactly the same principles as do the two immediately preceding, with the slight difference in detail that its short side is not at right angles to either upper or lower base. Also, in this case the bottom of the article appears inclined instead of the top. It will be seen at a glance that if the shape be considered as anything else than a flange against an inclined roof the drawing might be so turned upon the paper as to bring the line K L into a horizontal position, when it would present the same conditions as those of Problems 193 and 194 with the slight difference in detail above alluded to.

The method of triangulation employed in this case is exactly the same as in the problem immediately preceding, and the operation is so clearly indicated by the lines and figures upon the four drawings here given as scarcely to need explanation, if the previous problem has been read. The plans of both top and bottom are divided into the same number of equal parts, and a view of the top as it would appear when viewed at right angles to the base line K L, and as shown by F G H, is projected into the plan of base, as indicated by the lines drawn from B C at right angles to A D.

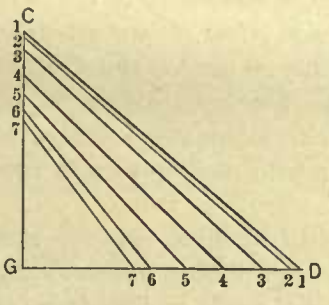


Fig. 637.—Diagram of Triangles Based upon the Solid Lines of the Plan in Fig. 636.

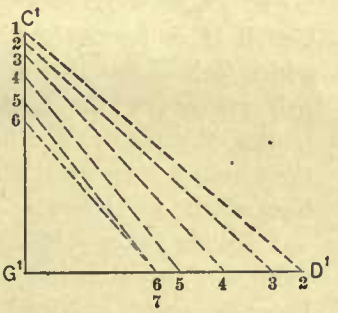


Fig. 638.—Diagram of Triangles Based upon the Dotted Lines of the Plan in Fig. 636.

Points of like number in the two curves F H G and A J D are joined by solid lines, and the four-sided figures thus obtained are redivided diagonally by dotted lines. These solid and dotted lines become the bases of the several right angled triangles shown in Figs. 637 and 638, whose altitudes are equal to the hights given between the lines B C and F G, and whose hypothenuses give correct distances across the pattern between points indicated by their numbers. The pattern is developed in the usual manner by assuming any straight line, as C D in Fig. 639, equal to C D of Fig. 636, as one end of the pattern, and then adding one triangle after another in their numerical order; using the stretchout of B E C, Fig. 636, to form the upper line of the pattern, the stretchout of A J L to form the lower side of the pattern and the various dotted and solid hypothenuses

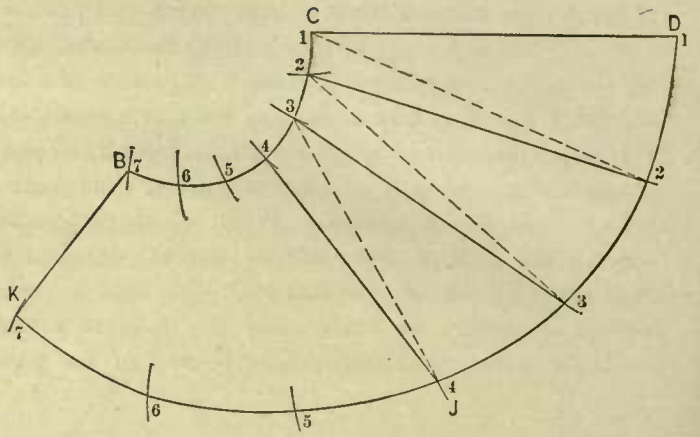


Fig. 639.—Pattern of Flaring Flange Shown in Fig. 636.

in Figs. 637 and 638 alternately to measure the distances across the pattern.

PROBLEM 196.

Pattern for an Irregular Flaring Article, Elliptical at the Base and Round at the Top, the Top and Bottom not Being Parallel.

The conditions given in this problem are essentially the same as those of Problem 193, but the following solution differs from that of the former problem in the method of finding the distances from points assumed in the base to those of the top, and is introduced as showing varieties of method: In Fig. 640, C G H D represents the side view of the article, of which G K H is a half profile of the top and C F D a half profile of the base. For convenience in obtaining the pattern the half profiles are so drawn that their center lines coincide with the upper and lower lines of the elevation.

Divide both of the half profiles into the same number of equal parts—in the present instance eight. From the points obtained in the half profiles drop perpendiculars cutting G H and C D. Connect the points secured in G H with those in C D, as *a n*, *b m*, etc. Also connect the points in G H with those in C D, as indicated by the dotted lines 1 *n*, *a m*, etc. Reference to Problem 193 will show that in order to obtain the correct lengths represented by the several solid and dotted lines drawn across the elevation complete sections upon those lines were constructed, as shown in Figs. 628 and 629. In the present case these distances will be derived from a series of triangles whose bases are the differences between the lengths of the lines drawn across the half profile of the top and those of the bottom.

Therefore, to obtain the triangles giving the true distances represented by the solid lines proceed as follows:

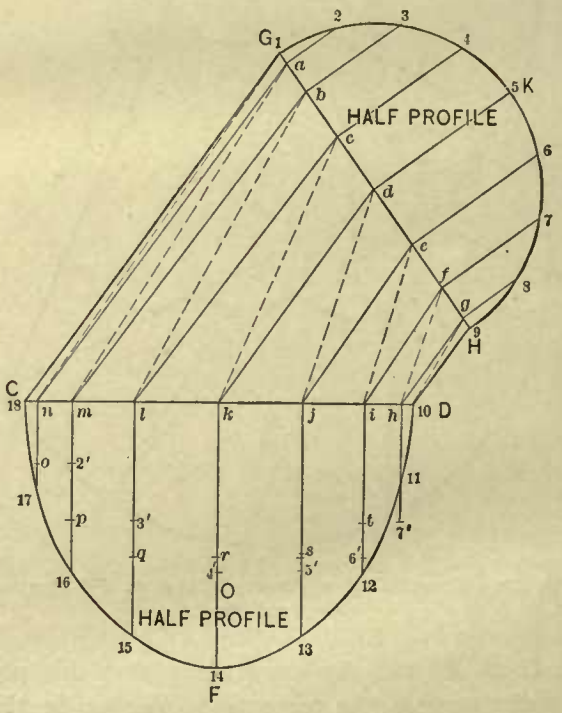


Fig. 640.—Elevation and Profiles of an Irregular Flaring Article, Showing Method of Triangulation.

First set off from C D upon each line in the base C F D the length of the corresponding line in the top; thus

make $n\ o$ equal to $a\ 2$, $m\ p$ equal to $b\ 3$, $l\ q$ equal to $c\ 4$, etc. For the bases of the triangles represented by the dotted lines set off from C D the length of corresponding lines in G K H, as shown by the small figures in C O D. Thus make $m\ 2'$ equal to $a\ 2$, $l\ 3'$ equal to $b\ 3$, $k\ 4'$ equal to $c\ 4$, etc. The triangles represented by solid lines in the elevation, and shown in Fig. 641, are obtained as follows: Draw the line P Q, and from a convenient point erect the perpendicular R S. From R on R S set off the lengths of solid lines in C G H D, and from R on P Q set off the lengths of corresponding lines in C O D F, as indicated by the small letters in C O D. To avoid a confusion of lines the lengths from C to O are set off to the left of R, and the lengths from O to D on R Q. Thus make R a' of diagram equal to $n\ a$ of Fig. 640, R o' of diagram equal to o 17 of half profile of base, and connect $a'\ o'$. Make R b' of diagram equal to $m\ b$ of Fig. 640, R p' of diagram equal to p 16 of the base, and connect $p'\ b'$, etc.

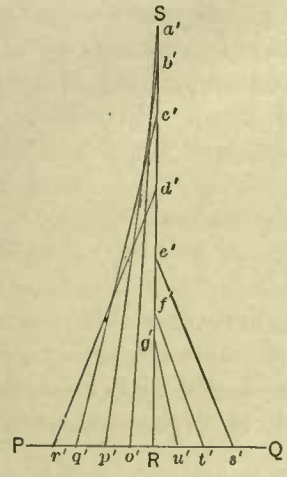


Fig. 641.—Diagram of Triangles Representing Solid Lines of the Elevation.

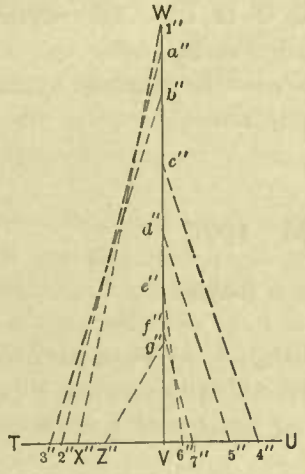


Fig. 642.—Diagram of Triangles Representing Dotted Lines of the Elevation.

The triangles represented by dotted lines in C G H D are obtained in a similar manner. Draw the line T U in Fig. 642 and erect the perpendicular V W. From V, on V W, set off the lengths of dotted lines in C G H D of the elevation. Thus make V 1″ equal to n 1 of Fig. 640, V a'' equal to $m\ a$, V b'' equal to $l\ b$, etc. Upon V T or V U set off the lengths of the lines in C O D F of Fig. 640, as indicated by the small figures. Thus make V X″ equal to n 17 of the base in Fig. 640, and draw X″ 1″. Make V 2″ equal to 2′ 16 of the base, and draw 2″ a'', etc.

To obtain the pattern first draw the line C G of Fig. 643, in length equal to C G of Fig. 640. From C, with radius equal to C 17 of the half profile of base, strike a small arc (o), which intersect with another arc struck from G as center, and 1″ X″ of Fig. 642 as radius, thus establishing point o in the curve of the pattern. From G of pattern as center, and G 2 of the half profile of top as radius, strike a small arc, which intersect with another arc struck from o of pattern as center, and $a'\ o'$ of Fig. 641 as radius, thus establishing point a in the upper curve of the pattern. From o of pattern as center, and 17 16 in C F as radius, strike a small arc (p), which intersect with another arc struck from a of pattern as cen-

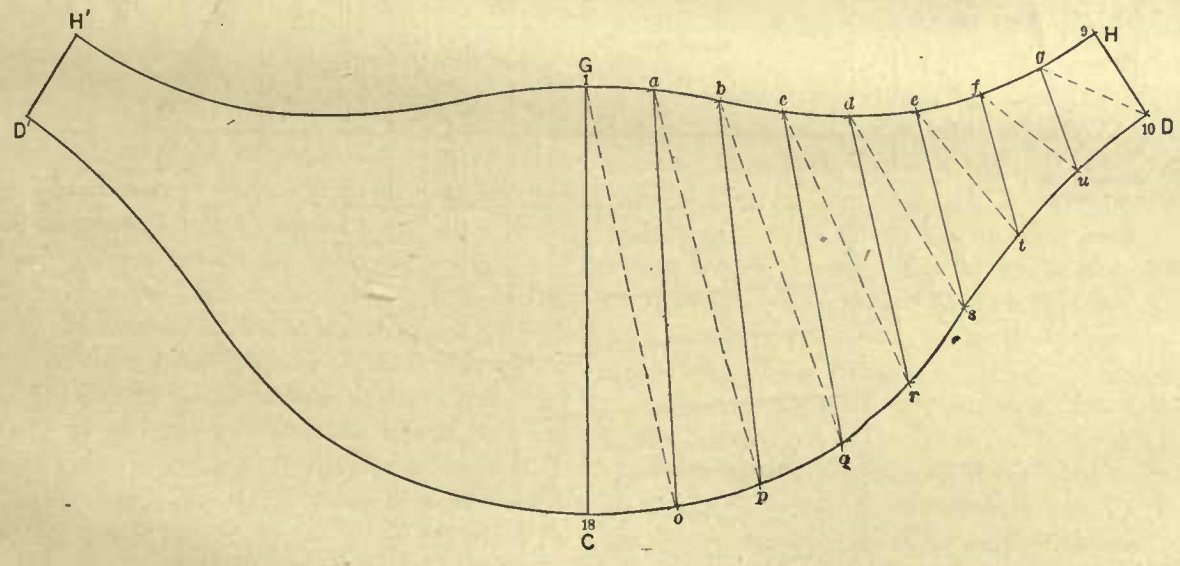


Fig. 643.—Pattern of Shape Shown in Fig. 640.

ter, and a'' $2''$ of Fig. 642 as radius, thus locating point p of the pattern. From a of the pattern as center, and 2 3 in G K as radius, strike a small arc, which intersect with another arc struck from p of pattern as center, and p' b' of Fig. 641 as radius, thus locating point b of pattern. Proceed in this manner, using in the order named the spaces in the lower profile, the hypothenuses of triangles in Fig. 642, the spaces in the upper profile, and the hypothenuses of triangles in Fig. 641. The points thus obtained, as indicated by the letters in Fig. 643, are the points through which the pattern lines are to be traced. Then C G H D is the required pattern for one-half the article. The other half of pattern, as shown by C G H′ D′, can be obtained by any convenient method of duplication.

PROBLEM 197.

The Patterns for a Bathtub.

In Fig. 644, let A B C D be the elevation and E F G H half the plan of a bathtub. An inspection of the drawing shows that neither the segments forming the head nor those of the foot of the tub are concentric, and that their upper and lower bases are not parallel. Therefore the figures which they constitute are irregular in character, and the only available method by which the various dimensions and curves constituting the patterns of the same can be ascertained is by dividing their surfaces into small triangles, which can most easily be accomplished in the following manner: Divide each of the curves J I and G H, forming the

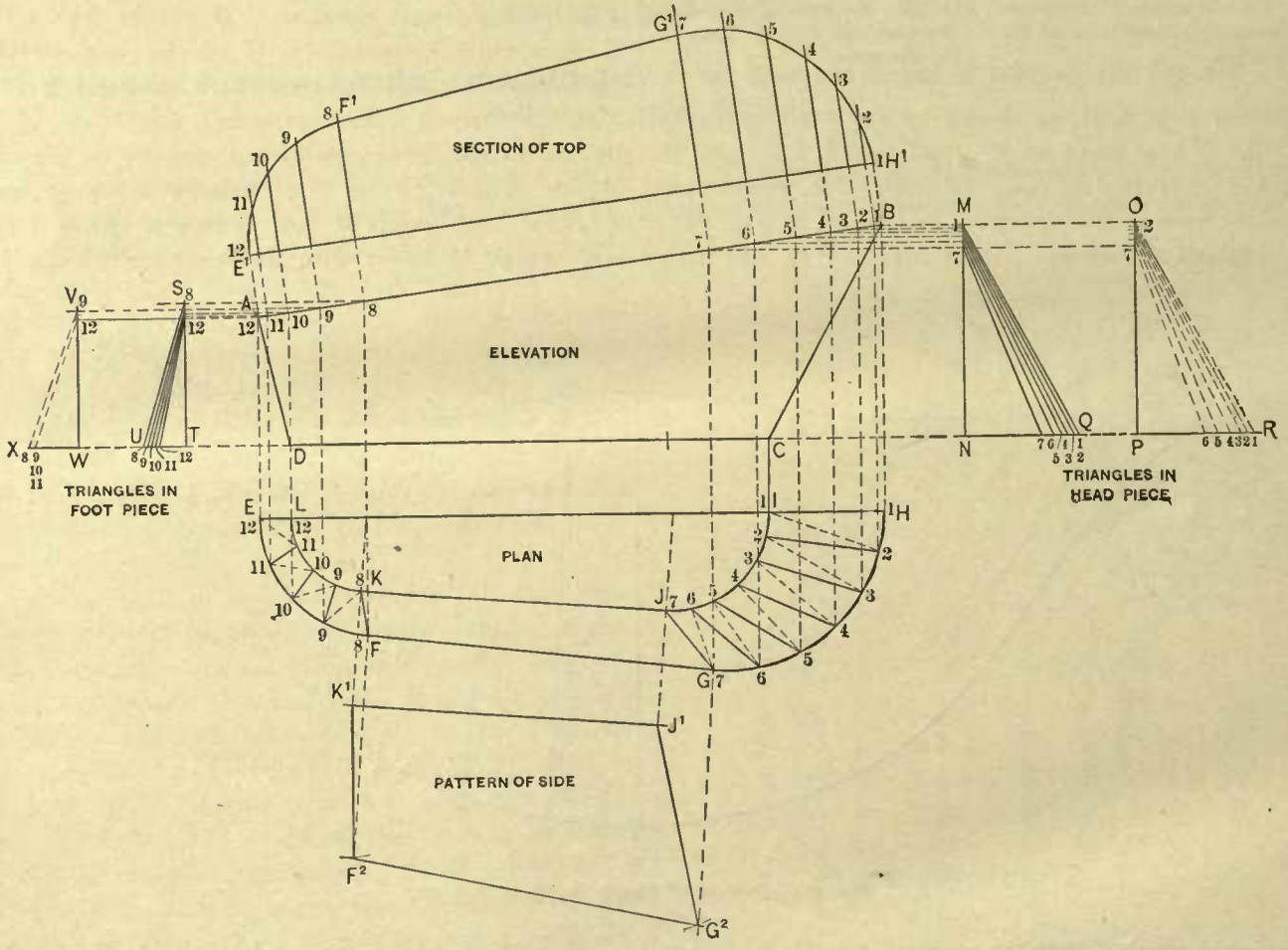


Fig. 644.—Plan and Elevation of Bathtub, with Diagrams of Triangles, Section of Top and Pattern of Side Piece.

plan of the head piece, into the same number of equal parts, numbering each the same, as shown, and connect points of similar number by solid lines. Also connect each point in J I, the line of the bottom, with the point of next higher number in G H, the line of the top, by a dotted line, all as shown. The curves E F and L K, forming the plan of the foot piece, are also to be divided into spaces and the points connected by solid and dotted lines in the same manner as those of the head.

The solid and dotted lines thus drawn between the points in the two curves of the plan will form the bases of a series of right-angled triangles, whose hypothenuses (after the altitudes are obtained) will give the real distance between the points whose number they bear upon the finished article. As, owing to the slant of the top line A B of the elevation, the triangles will

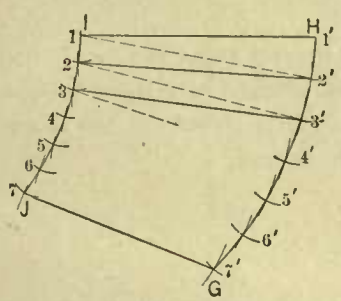


Fig. 645.—Half Pattern of Head Piece.

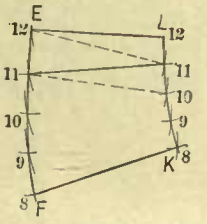


Fig. 646.—Half Pattern of Foot Piece.

be of differing hights, the simplest way of constructing them will be as follows: Upon D C of the elevation extended, as a base, erect a perpendicular line, M N From N on the base line set off the various lengths of the solid lines in the plan of the head piece, as shown toward Q. From each of the points in the curve G H erect perpendicular lines, cutting A B of the elevation; and from these points of intersection carry lines horizontally to the right, cutting the line M N, numbering each point to correspond with the points in G H, all as shown. Lines connecting points of similar number at M and Q will be the hypothenuses required, or the real distances between points of similar number in the top and bottom of the finished article. In a similar manner erect another perpendicular, O P, and set off from P on the base line the lengths of the several dotted lines in the plan of the head piece, as shown toward R. The hights of the points in the curve of the top can be determined upon the line O P by continuing the lines drawn from A B toward M till they intersect O P. Each point in the base P R is now to be connected with the point of the next higher number in O P by a dotted line. The various hypothenuses drawn between O and R will then be the correct distances between the points connected by the dotted lines of the plan. (The numbers in P R correspond with those in I J of the plan and not with H G). The diagrams from which the dimensions for the foot piece are obtained are shown at S T U and V W X at the left of the elevation and are obtained in a manner exactly similar to those just obtained for the head piece, all of which is clearly shown by the lines of the drawing.

From an inspection of the drawing it will be seen that the line E F G H does not represent the true lengths or measurements taken on the top line of the tub, because A B, not being horizontal, is longer than the line E H, its equivalent in the plan, and therefore a true section on the line A B must be obtained, as shown above the elevation. This may be accomplished in the following manner: At any convenient distance above A B draw E' H' parallel to A B, and from all of the points previously obtained on A B carry lines at right angles to A B, cutting E' H', and extend them beyond indefinitely, numbering each line to correspond with the point in E F G H from which it is derived. On the line 2 set off from E' H' a distance equal to the distance of point 2 of the plan from the line E H as measured on the vertical line; on line 3 set off as before a distance equal to the distance of point 3 of the plan from E H, and so continue until the distances from E H of all the points in E F G H have been transferred in like manner to the new section. Then a line traced through these points, as shown by E' F' G' H', will be a section or plan on the line A B, from which measurements can be taken in developing the upper edge of the pattern.

Having obtained, by means of the various diagrams constructed in connection with the elevation, the correct distances between all the points originally assumed in the plan, the pattern may now be developed by simply reproducing all of these distances or measurements in the order in which they occur upon the plan. For the pattern of the head piece assume any line, as I H of Fig. 645, which make equal in length to C B of the elevation, or what is the same thing, equal to 1 1 of the diagram M N Q. From H as a center, with a radius equal to 1 2 of the section of top, strike a small arc, which intersect with another arc struck

from I as a center, with a radius equal to 1 2 of the diagram of dotted lines O P R, thus establishing the point 2′ of the pattern. From 2′ as center, with a radius equal to 2 2 of the diagram of solid lines M N Q, strike a small arc, which intersect with another struck from point I as a center, with a radius equal to 1 2 of the line I J of the plan, thus establishing the point 2 of the pattern. Continue this operation, using in numerical order the distances taken from the top section, in connection with the distances obtained from the diagram of dotted lines O P R, to form the top line of the pattern, and the distances taken from the diagram of solid lines M N O, in connection with the distances measured upon the bottom line I J of the plan, to form the bottom line of the pattern, all as indicated by the solid and dotted lines drawn across a portion of the pattern. Then I H G J will be one-half the pattern of the head piece. The pattern for the foot piece is developed in exactly the same manner by making E L equal to A D of the elevation, and using the diagram of dotted lines V W X to measure upon the pattern the distances indicated by the dotted lines upon the plan, and the diagram of solid lines S T U to measure upon the pattern the distances indicated by the solid lines across the plan, the distances forming the top line of the pattern being taken from E′ F′ of the top section while the distances forming the bottom line of the pattern are taken from the line L K of the plan.

The pattern for the flat portion of the side F G J K can be obtained as follows: Parallel to K J of the plan draw any line, as K′ J′. At right angles to K J of the plan project lines from points K, J, F and G, cutting K′ J′, as shown, establishing the points K′ and J′, and continuing the lines from points F and G indefinitely. From K′ of the pattern as a center, with a radius equal to 8 8 of the diagram S T U, or of Fig. 644, strike a small arc, cutting the line projected from point F of the plan, as shown at F² of the pattern. From J′ of the pattern as a center, with a radius equal to 7 7 of the diagram M N Q, or of Fig. 644, strike a small arc, cutting the line projected from the point G of the plan, as shown at G². Draw the lines K′ F², F² G² and G² J′; then K′ F² G² J′ will be the pattern of the flat portion of the side.

The patterns of the several parts can be joined together, by any convenient method of duplication, in such a manner as to produce as much of the entire pattern in one piece as it is desired.

PROBLEM 198.

The Pattern for a Flaring Flange to Fit a Round Pipe Passing through an Inclined Roof; the Flange to Have an Equal Projection from the Pipe on All Sides.

In Fig. 647, let *a b c d* be the elevation of the pipe, E E′ its plan, A B C D the elevation of the flange and C D the angle or pitch of the roof. Since the projection of the base of the flange is required to be equal on all sides, as shown by C 1 and D 1, the flange will appear in the plan as a perfect circle, F F′. To avoid confusion of lines another elevation of the flange G H K J is shown in Fig. 648, below which is drawn a half plan of its base, M B N, and above which is a half plan of its top, G L H, all of which will be made use of in dividing the surface of the flange into measurable triangles for the purpose of developing a correct pattern of the same.

Divide the semicircle G L H into any convenient number of equal parts—in the present instance 12—and from the points thus obtained drop perpendicular lines to G H. To obtain the shape of section on roof line J K divide the half plan of base M B N into the same number of equal parts as was G L H, and from the points thus obtained carry lines at right angles to M N, cutting J K. From the points in J K draw lines at right angles to it, as shown by *a* 1, *b* 2, *c* 3, etc. On these lines, measuring from J K, set off the length of corresponding lines in M N B, thus making lines *a* 1, *b* 2, *c* 3, etc., in J K C equal to lines *a* 1, *b* 2, *c* 3, etc., in M N B. A line traced through these points, as shown by J C K, will give the shape of section on roof and furnish the stretchout of base for obtaining the pattern.

In Fig. 649 is drawn a duplicate of the plan in Fig. 647, the spaces in its outer line O D P being exact duplicates of the spaces in M B N of Fig. 648,

and the spaces in its inner line O′ D′ P′ being duplicates of those in G L H, all as shown by the small figures. Draw solid lines connecting similar points, as 1′ 1, 2′ 2, 3′ 3, etc. In like manner connect the

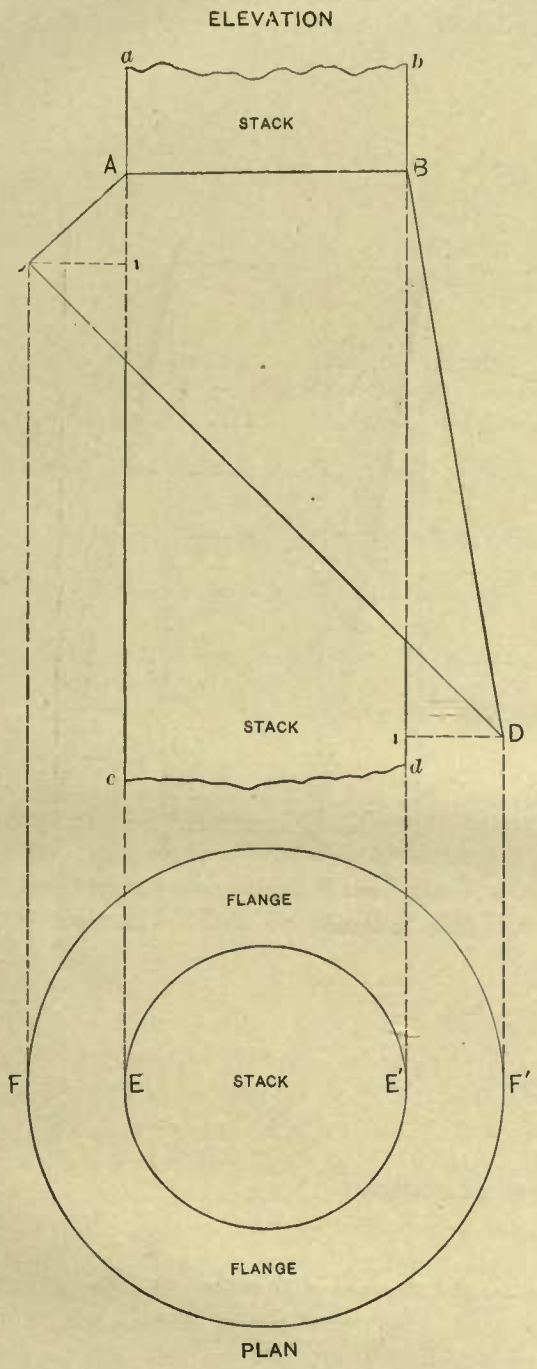


Fig. 647.—Plan and Elevation of Pipe and Flange.

points in O′ D′ P′ with those of the next higher number in O D P, as 0 with 1′, 1 with 2′, 2 with 3′, etc., with dotted lines. These solid and dotted lines will then form the bases of a series of right angled triangles, whose altitudes can be derived from the elevation, and whose hypothenuses, when obtained, will be the correct measurements across the pattern between points of numbers corresponding with the lines across the plan.

To construct the diagrams of triangles represented by solid and dotted lines in plan, extend G H of Fig. 648 indefinitely, as shown by H W. From the points in J K carry lines to the right indefinitely, parallel with G W, as shown by the lines between G W and K Y. At any convenient place, as R, and at right angles to G W, erect the line R S, cutting the base line K Y. From R set off the distance R T, equal to the length of any of the solid lines in plan, Fig. 649, as P′ P, which is the horizontal distance between the pipe and lower edge of the flange. Draw T U parallel with R S, and also draw lines from the points in R S to T. For convenience the points in R S can be numbered to correspond with the points in J C K. Then the triangle T U S will correspond to a section through

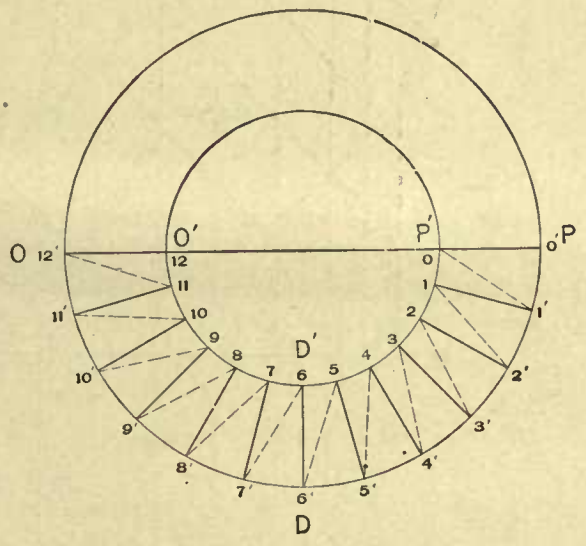


Fig. 649.—Plan of Flange, Showing Triangulation.

the article on the line P′ P in plan, the hypothenuse S T representing the distance between the pipe and lower edge of the flange. The diagram of triangles in V W Y X is constructed in a similar manner; draw W Y at right angles to G W, and set off the space W V equal to the length of one of the dotted lines in plan, Fig. 649, as 0 1′, and draw lines from the points in W Y to V.

In developing the pattern the stretchout of top of

flange where it joins the pipe can be obtained from the semicircle G L H. The stretchout of lower edge of flange where it joins the roof can be obtained from the section on the roof line J C K. The distance between points in O D P and O′ D′ P′ of plan, Fig. 649, length to T S of first diagram of triangles. With the dividers set to the distance K 1 in K C J of section strike a small arc (1′) from the point 0′ of pattern. With the dividers set to the distance V 1 of second diagram of triangles strike a small arc from the point 0 of

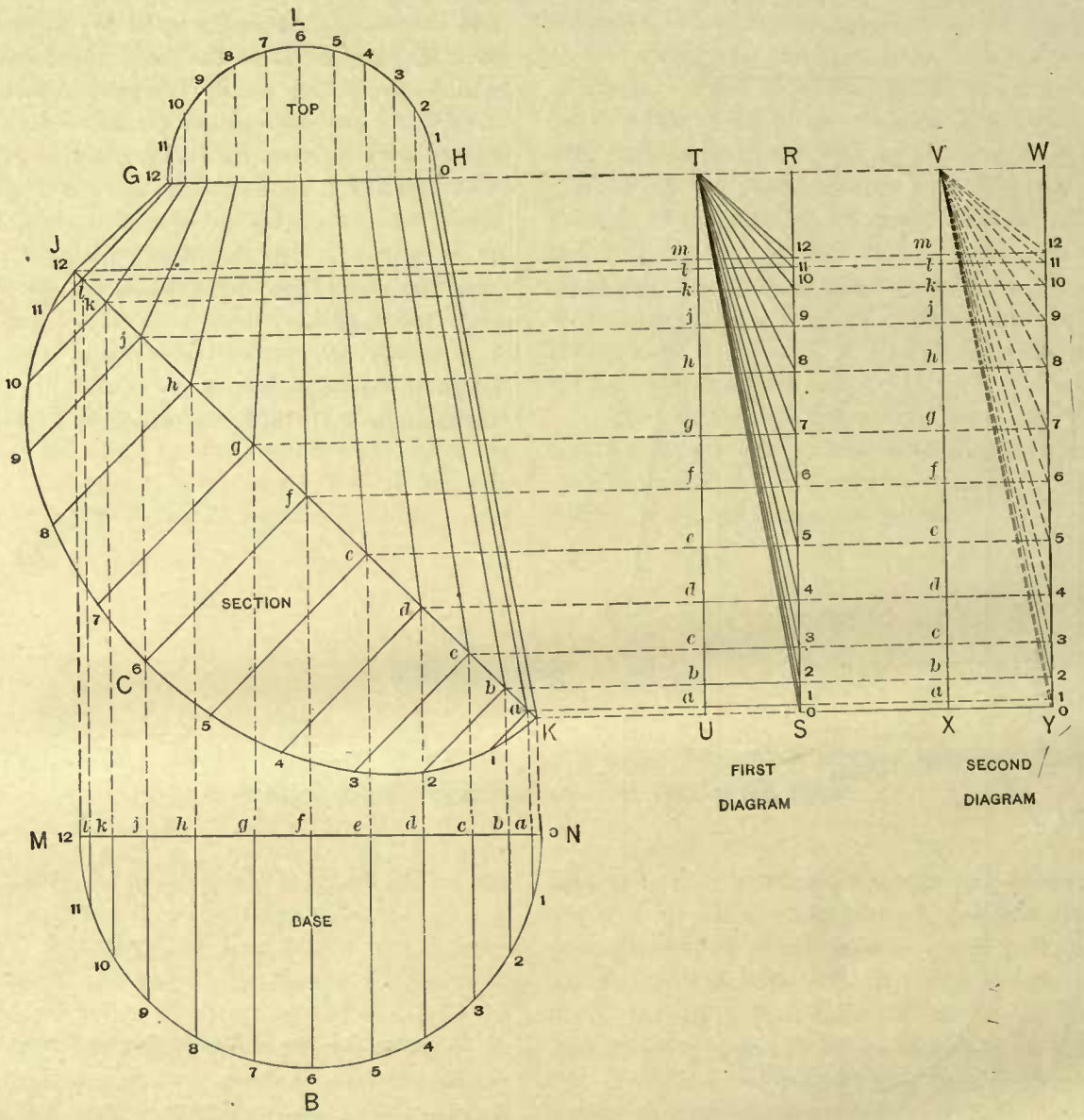


Fig. 648.—Elevation of Flange, with Plan, Sections and Diagrams of Triangles.

as indicated by the solid lines, is given in the diagram of triangles T R S. The distance between points as indicated by dotted lines in plan is given in the diagram V W Y. For the pattern then proceed as follows: Draw any line, as H′ K′, Fig. 650, equal in pattern as center, cutting the first arc at 1′ of pattern. From point 1′ of pattern as center, and T 1 of first diagram of triangles as radius, describe a small arc (1), which intersect with one struck from 0 of pattern as center, and 0 1 in H L G as radius. Thus the points

0 0′ and 1 1′ of pattern are established. Proceed in this manner, using in the order described the stretchout obtained from the elliptical section K C J, the hypothenuse of triangle in second diagram corresponding to the dotted line in plan, the stretchout from the section G L H, and the hypothenuse of triangle in the first diagram corresponding to the solid line drawn across the plan, until all the measurements are used. Lines traced through the points thus obtained, as shown by H′ G′ and K′ J′, will be the half pattern. The other half of the pattern can be obtained by any means of duplication most convenient.

Should it be required to construct such a flange to fit over the ridge of a roof, it is clear that that part of the flange shown in the plan, Fig. 649, by O O′ D′ D would be a duplicate of the part shown by D′ P′ P D, and that, therefore, that portion of the pattern, Fig. 650, shown by 6 H′ K′ 6′ would be one-quarter of the entire pattern, which could be duplicated so as to make either one-half or the whole pattern in one piece.

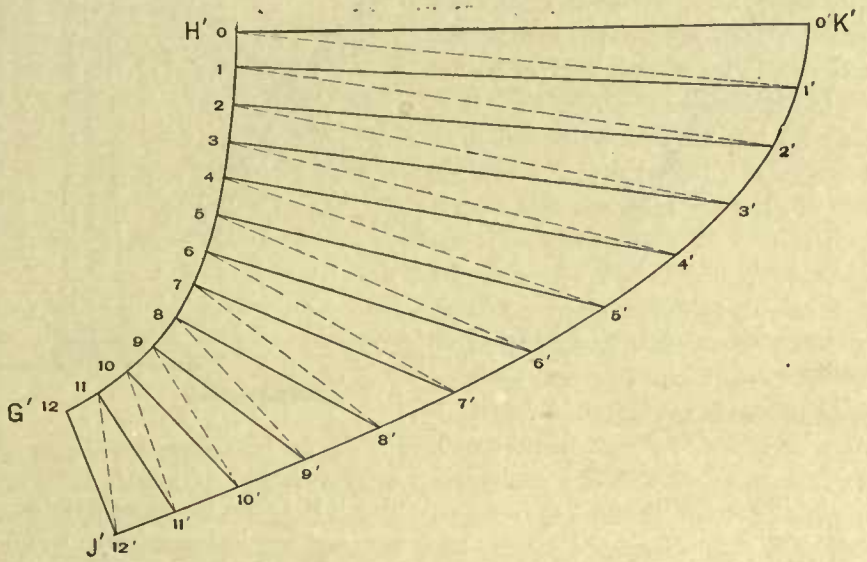


Fig. 650.—Half Pattern of Flange Shown in Fig. 647.

PROBLEM 199.

Pattern for the Hood of a Portable Forge.

In Fig. 651, C A B D represents the front elevation of a hood such as is frequently used upon a portable forge, K L M N its plan and E F H J *a* its side view. The opening A B at the top of the hood is round, as shown by L P of the plan, while the base C D where it joins the forge is nearly semi-elliptical, as shown by K L M of the plan. In the side elevation E *a* shows the amount of flare and projection of the front of the hood, while the opening, shown in the front by C S D, appears as a simple straight line, *a* J. With these conditions given, the arch of the opening C S D of the front elevation can be determined in connection with the plan, by projection, as shown by the horizontal dotted lines, while if the arch of the front elevation be assumed arbitrarily then its line (*a* J) in the side view must be obtained by projection, and will be either

straight or curved according to the nature of the curve employed in the front elevation.

Assuming the straight line *a* J of the side view as the true profile of the arch, its curve in either the front elevation or the plan must be determined, as a means

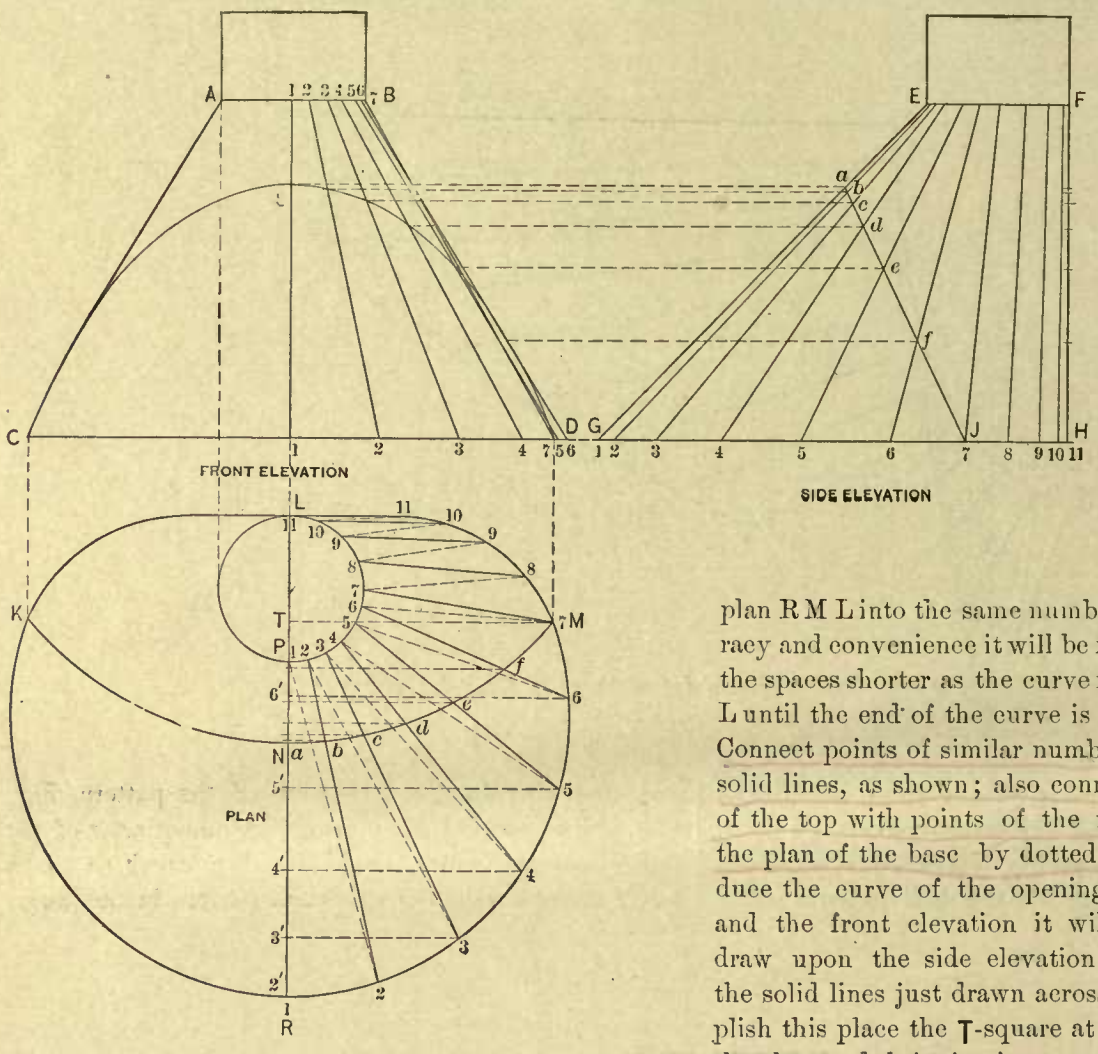


Fig. 651.—Front and Side Elevations and Plan of Hood, Showing System of Triangulation.

of obtaining the pattern. As the flaring portion of the hood very much resembles a conical frustum having an oblique base, probably the simplest method of arriving at its true shape is to first determine the plan of this irregular frustum of which it is a part. Therefore produce the oblique line E *a* of the side elevation until it intersects the base line H J extended in the point G. Next set off from L on the center line of the plan a distance equal to H G of the side elevation, thus locating the point R. Through R, from a center to be determined upon the center line, draw the curve forming the front of the plan, with such length of radius as will make an easy junction with the curves of the back at K and M. It is not necessary that the curve K R M should be a perfect circle throughout; it may change as it approaches K and M so as to flow smoothly into the assumed curve of the back. It is simply necessary that no angle be produced at K and M, as such an angle would be continued through the surface of the hood toward the opening of the top.

Divide the circle of the top P L into any convenient number of equal spaces, as shown by the small figures; also divide the outer curve of the plan R M L into the same number of spaces. For accuracy and convenience it will be found advisable to make the spaces shorter as the curve increases from M toward L until the end of the curve is reached at the point 11. Connect points of similar number in the two curves by solid lines, as shown; also connect points in the plan of the top with points of the next higher number in the plan of the base by dotted lines. In order to produce the curve of the opening correctly in the plan and the front elevation it will be necessary first to draw upon the side elevation lines corresponding to the solid lines just drawn across the plan. To accomplish this place the T-square at right angles to L R of the plan, and, bringing it successively against the points in the plan of the base R M L, drop corresponding points on L R, as shown. Transfer the spaces thus produced to the base line H G of the side elevation, numbering each point to correspond with the plan. By means of the T-square placed as before, drop points from the plan of the top to the center line L P (omitted in the drawing to avoid confusion of lines) and transfer the same to the line F E of the side elevation, numbering each point as before. Now connect points of corresponding number in the upper and lower lines of the side elevation by solid lines, as shown; then will these lines be the elevations of the solid lines drawn across the plan.

It may be here remarked that, as the pattern will be obtained from the plan, a correct front elevation of the opening, or arch, is not necessary to the work, but if it is desired it can be obtained in the following manner: Place the T-square parallel to L R of the plan and, bringing it against the points in the plan of the

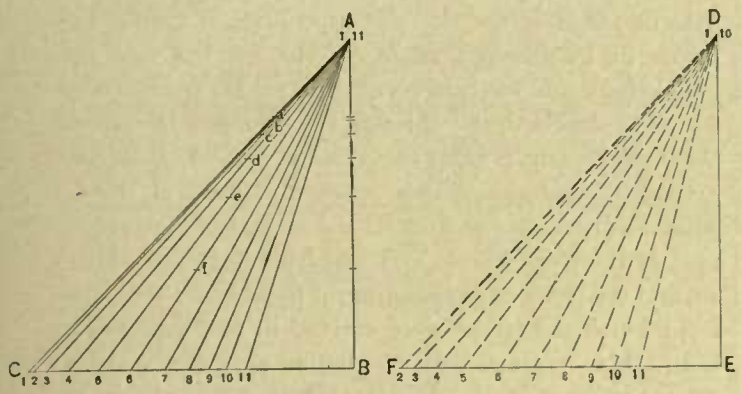


Fig. 652.—Diagrams of Triangles.

base between R and M, drop corresponding points on the base line C D of the front elevation. Also in the same manner drop points from the curve of the top L P in plan upon A B of the front elevation, and connect points of corresponding number in the two lines by solid lines, as shown. From the points of intersection of the solid lines in the side elevation with the line *a* J (the profile of the arch), *a*, *b*, *c*, etc., carry lines horizontally across, as shown, intersecting them with lines of corresponding number in the front elevation. A line traced through the points of intersection as shown from S to D, will be the correct elevation of the opening in the front of the hood.

The correct plan of the opening may be obtained by placing the T-square parallel to L R and bringing it against the various points of intersection through which the curve S D was traced and cutting the solid lines of corresponding number in the plan, giving the points *a*, *b*, *c*, etc. In case the development of the curve S D has been omitted, measure the horizontal distance of each of the points *a*, *b*, *c*, etc., in *a* J of the side elevation from the line F H and set off the same on the center line of the plan from L toward N. Thus the horizontal distance of point *a* from the line F H is set off from L on the center line of the plan, thus locating the point N or *a*, the extreme point of projection of the hood. In the same manner the projections of points *b*, *c*, etc., of the side elevation, or in other words, their distances from F H are set off from L of the plan, as shown between N and T. Now place the T-square at right angles to L R and, bringing it against these points last obtained, cut the corresponding solid lines of the plan, thus locating the points *a*, *b*, *c*, etc., of the plan, as before. A line traced through these points will be the correct plan of the curve of the opening.

Before the pattern can be begun it will be necessary to first obtain the correct distances represented by the solid and dotted lines across the plan. This is accomplished by means of two diagrams of triangles, shown in Fig. 652, as follows: Draw the vertical line A B, in length corresponding to the hight of the hood, as indicated by F H in the side elevation. At right angles to A B draw B C, in length corresponding to P R or 1 1 of the solid lines of the plan. From B set off also the spaces B 2, B 3, B 4, etc., corresponding in length to the lines 2 2, 3 3, 4 4, etc., of the plan. Connect the points in B C with the point A by solid lines. Then will these lines represent the true distances between points 1 and 1, 2 and 2, etc., of the plan. The second diagram of triangles is constructed in a similar manner. The vertical line E D is drawn, equal to F H of the side elevation. E F is set off at right angles to it, in length equal to the dotted line 1 2 of the plan. From E are set off the distances E 3, E 4, etc., corresponding to the lines 2 3, 3 4, etc., of the plan. The points thus established in F E are then connected with D by means of dotted lines. Then will these lines represent the

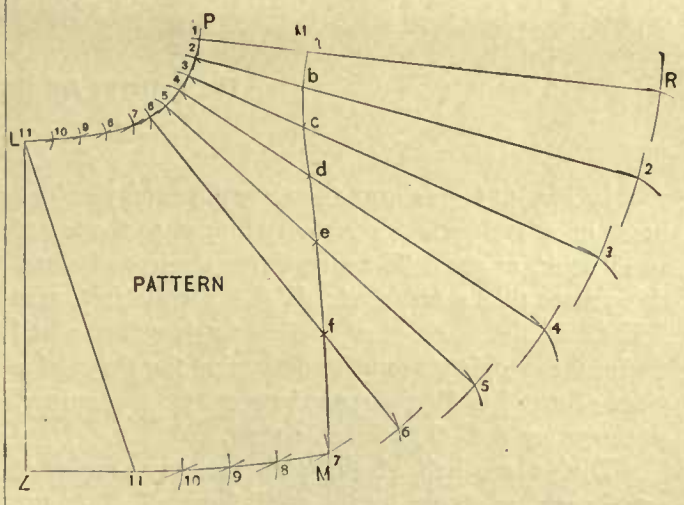


Fig. 653.—Pattern of Hood.

true distances between points 1 and 2, 2 and 3, etc., of the plan.

To develop the pattern, first draw any vertical line, as L Z of Fig. 653, representing the center of the

back, which make equal to the hight of the hood F H. As the base of the hood is perfectly straight from L to the point 11, set off on a horizontal line from the point Z, in Fig. 653, a distance equal to L 11 of the plan, and draw 11 L of the pattern. With L as center, and 11 10 of the small circle in plan as radius, describe a short arc. Then, from 11 of the base in pattern as center, and 11 D of the second diagram of triangles as radius, describe a short arc intersecting the one first drawn, thus establishing the point 10 of the upper line of the pattern. Then from this point as center, with A 10 of the first set of triangles as radius, describe a short arc, and from 11 of the base of the triangular portion of the pattern, with 11 10 of the outer curve of the plan as radius, describe another arc intersecting it, thus establishing the point 10 in the lower line of the pattern. Proceed in this manner, using alternately the spaces in the inner line of the plan, the hypothenuses of the dotted triangles, the hypothenuses of the triangles indicated by solid lines, and the spaces in the outer line of the plan, obtaining the several points, as shown. Then lines traced through these points will be the pattern of the envelope of the shape indicated by F E G H of the side elevation, or in other words, of the frustum of which the hood forms a part. It now remains to cut away such a portion of this pattern as represents the part G *a* J of the side elevation. To accomplish this it is simply necessary to obtain the positions of the points *a*, *b*, *c*, etc., of the plan and side elevation upon the lines 1 1, 2 2, 3 3, etc., of the pattern.

With the blade of the T-square set parallel to the base line G H of the side elevation bring it against the points of intersection made by the line *a* J with the radial lines, and cut the vertical line F H, as shown by the short dashes drawn through it. Transfer the points thus obtained in F H to the vertical line A B of the first set of triangles. Then with the blade of the T-square at right angles to A B, and brought successively against the points in it, cut the hypothenuses of the several triangles corresponding in number to the lines from which the points were derived in the side elevation, all as indicated by the letters *a*, *b*, *c*, *d*, *e* and *f*. The distances of these points from A may now be transferred to lines of corresponding number in the pattern, measuring from the upper line, as shown by *a*, *b*, *c*, etc. Then a line traced through these points, as shown from N to M, will give the shape of the front or arch of the hood, and L P N M Z will be the half pattern of the hood.

PROBLEM 200.

The Patterns for the Hood of an Oil Tank.

In Fig. 654 are shown the elevations and plan of a hood of a style which is usually hinged to the top of an oil tank, or can. The plan shows a curve of something more than a semicircle, H′ G F′, while the curve F K H of the back view is slightly less than a half circle, the problem being to determine the shape of a piece of metal to fill the space between the two curves, as shown by A B C of the side view.

Divide one-half of the plan into any number of equal parts, as shown by the small figures 1, 2, 3, etc. From the points established in the plan carry lines upward until they cut the base line of the required piece, as indicated by the points between A and B. From the points thus established carry lines parallel to A C until they cut the line representing the back of the hood, as shown between C and B, thence carry them horizontally until they cut the profile of the back of the hood, as shown by the points between K and F. From the points in K F drop lines vertically on to the base line F E, establishing points in it, as shown. Lay off spaces in the line F′ E′ of the plan corresponding to those of F E in the back, and from the points thus established draw solid lines to those of corresponding numbers laid off in the plan from G to F′. These lines represent the bases of a series of right angled triangles whose altitudes are shown by the dotted lines of the back view, and whose hypothenuses will give the correct distances between points of similar number in the plan.

As the altitudes of these triangles are also shown in C B of the side elevation, that view is here made use of for the purpose of obtaining the required hy-

pothenuses. However, since the solid lines drawn across the plan are not parallel to G E′, the distances 1 B, 2 B, etc., representing them in the base line of the

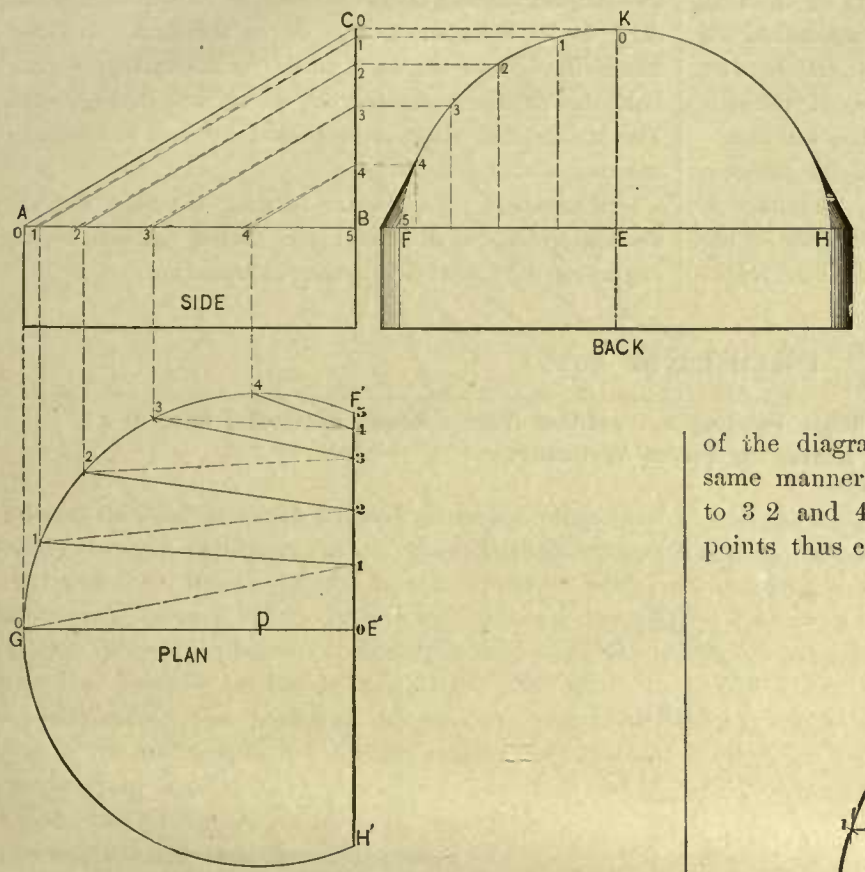


Fig. 654.—Elevations and Plan of Hood for an Oil Tank, Showing System of Triangulation.

side view will not be the correct bases of the triangles, therefore set off on A B, measuring each time from B, the correct lengths of the several solid lines of the plan, as indicated by the points near 1, 2, 3, etc., on the line

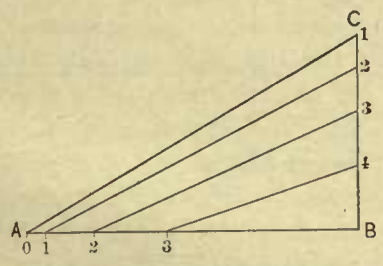


Fig. 655.—Diagram of Triangles Based upon the Dotted Lines of the Plan.

A B, from which points draw lines (shown dotted) to points of similar number in B C. Then the dotted lines 1 1, 2 2, etc., of the side view will be the correct hypothenuses of the triangles whose bases are indicated by the solid lines drawn across the plan. To complete the measurements necessary for obtaining the pattern connect the points in the opposite sides of the plan diagonally, as, for example, 0 of the front and 1 of the back, and 1 of the front with 2 of the back, as shown by the dotted lines. These dotted lines represent the bases of a second set of triangles, to be constructed in the same manner as the former set, all as shown, Fig. 655. Draw A B and B C at right angles to each other and upon C B set off the several hights shown in C B of Fig. 654. Upon A B lay off B 0, corresponding in length to 1 0 in the plan. Make B 1 of the diagram equal to 2 1 of the plan, and in the same manner make B 2 and B 3 of the diagram equal to 3 2 and 4 3 of the plan respectively. From the points thus established in the base line of the diagram

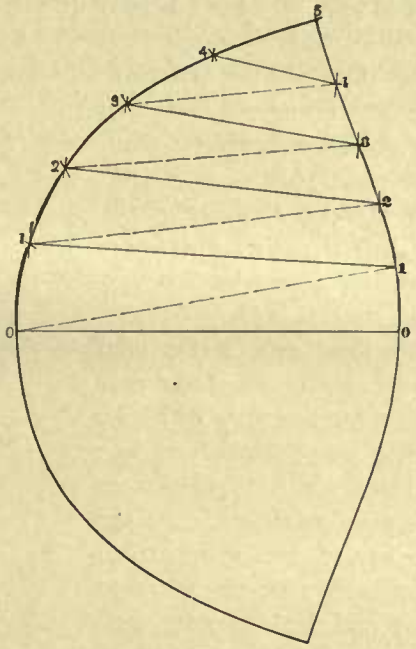


Fig. 656.—Pattern for the Top of Hood.

draw lines to points of next higher number in the vertical line. These hypothenuses will then represent lengths of lines measured on the face of the hood corresponding to the diagonal dotted lines in the plan.

To develop the pattern, first draw any line, as 0 0 of Fig. 656, equal in length to A C of side, Fig. 654. From **0**, at the right of the pattern, as center, with the distance between the points 0 to 1 in the profile F K of the back as radius, describe a short arc.

Next take in the dividers the distance 0 1 of Fig. 655, and from the opposite end of the center line describe a short arc, intersecting the one already drawn at the point 1, thus establishing that point. From 1 as center, with dotted line 1 1 of the side view as radius, describe another short arc, which in turn intersect by an arc struck from 0 of the left hand side of the pattern with 0 1 of the plan as radius. This will establish the point 1 of the opposite side of the pattern. Continue in this way, intersecting the hypothenuse of the triangles whose bases are the dotted lines of the plan with the measurements taken from the back view, and the hypothenuse of the triangles which are shown by the solid lines of the plan with the measurements taken from the circumference of the plan. In this manner all points in the profile of the pattern necessary to its delineation will be established. A free-hand line drawn through these points will give one-half the required pattern, all as shown in Fig. 656. The other half may be obtained by any convenient method of duplication.

The shape of patterns forming the back and the vertical sides of the hood are clearly shown in the engraving and need no further explanation.

PROBLEM 201.

Pattern for an Irregular Flaring Shape Forming a Transition from a Round Horizontal Base to a Round Top Placed Vertically.

In Fig. 657, let I D E F H represent the front elevation of the article, showing the circular opening D E F G forming its upper perimeter or profile. The triangle A B C shows the shape of the article as it appears when viewed from the side, below which is drawn the plan, showing its circular base, J K L M. The line N P shows the plan of the opening D E F G, which opening is shown in the side view by that portion of the line A B from A to Q. Opposite the front side of the plan N P is drawn a duplicate of the profile D E F G, as shown by E′ F′ G′, so placed that its vertical center line E′ G′ shall coincide with the center line of the plan, as shown. As the article consists of two symmetrical halves it will only be necessary to develop one-half the complete pattern. Therefore divide one-half of both profiles E F G and E′ F′ G′ into the same number of equal parts, numbering each in the same order, as shown by the small figures; also divide the plan of the base into the same number of equal parts as the profile, numbering the points to correspond with the same. Drop lines from the points on the profile E′ F′ G′ on to the line N P, at right angles to the same, as shown, and connect these points with those of similar number upon the plan of base by solid lines, as shown. Also connect points upon the base with those of the next higher number upon the line N P by dotted lines.

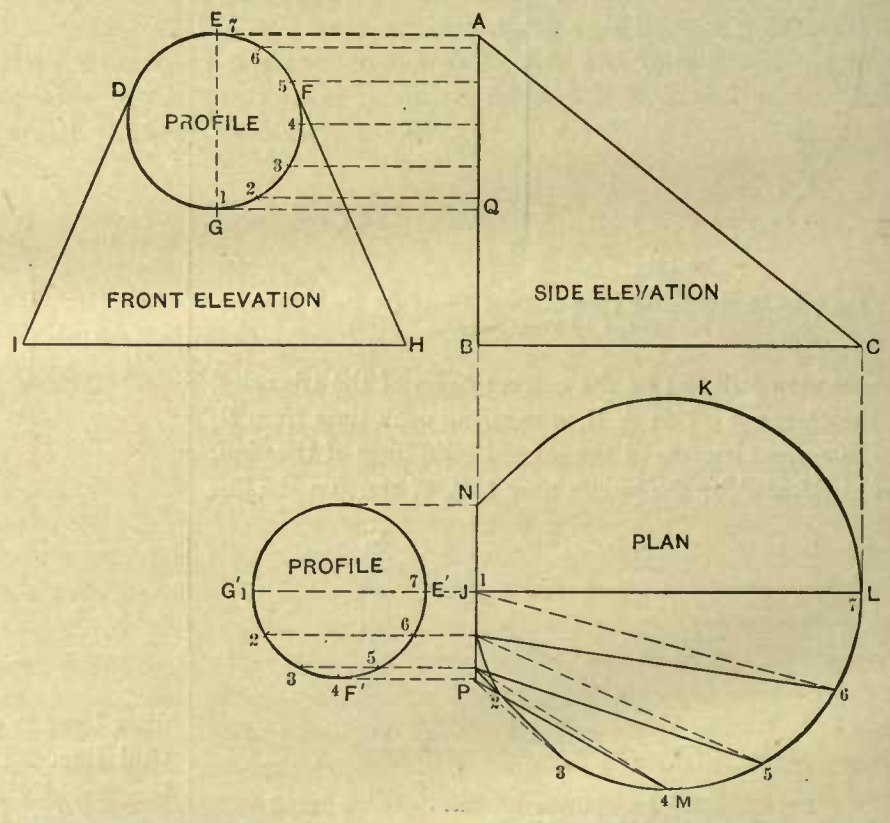


Fig. 657.—Elevations and Plan of an Irregular Shape Forming a Transition from a Round Horizontal Base to a Round Top Placed Vertically.

It will be noticed that the point J of the plan

represents at once the point 1 of the base and the points 1 and 7 of the profile, shown by B, Q and A of the side elevation. The lines drawn across the plan represent the horizontal distances between the

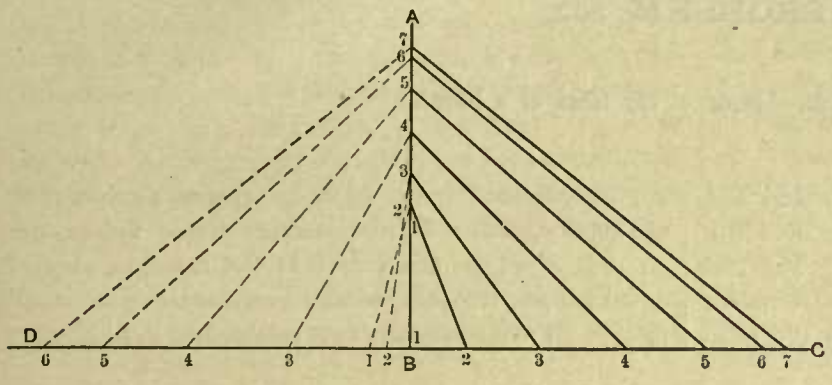


Fig. 658.—Diagram of Triangles.

points which they connect and will form the bases of a series of right angled triangles, whose altitudes can be derived from the elevations, as will be shown, and whose hypothenuses, when drawn, will give the true distances between points of corresponding number across the finished article or its pattern. To obtain the altitudes of the triangles carry lines from the points in the half profile E F G horizontally across, cutting the line A Q, as shown; then the distances of the points in A Q from B will constitute the respective altitudes of the triangles. Therefore, to construct a diagram of all the triangles, draw any horizontal line, as D C, Fig. 658, near the center of which erect a perpendicular, B A. Upon B A set off from B the various distances from B to points in A Q of Fig. 657, numbering the same as shown by the small figures. From B set off on B C the lengths of the various solid lines drawn across the plan, Fig. 657, and connect points in B C with those of like number in B A. From B set off toward D the lengths of the various dotted lines drawn across the plan and connect them by dotted lines with points of the next higher number in the line B A, all as shown; then these various hypothenuses will constitute the true distances across the finished article between points of corresponding number indicated on the plan and elevations. The distances between points in the base line forming the larger or outer curve of the pattern can be measured from the base line in plan, while spaces forming the upper or shorter side of pattern can be measured from either of the profiles.

To develop the pattern it is simply necessary to construct the various triangles whose dimensions have been obtained in the previous operations, beginning at either end most convenient and using the dimensions in the order in which they occur until all have been used and the pattern is complete.

Therefore, upon any straight line, as A C of Fig. 659, set off a distance equal to A C of Fig. 657 or the solid line 7 7 of Fig. 658. From C as a center, with a radius equal to 7 6 of the plan, Fig. 657, describe a small arc to the left, which intersect with another small arc struck from A as a center, and with a radius equal to the dotted line 7 6 of the diagram of triangles, Fig. 658, thus establishing the position of the point 6 of the pattern. From A of Fig. 659 as center, with a radius equal to 7 6 of the profile, Fig. 657, describe a small arc, which intersect with another struck from point 6 of pattern as center, with a radius equal to the solid line 6 6 of Fig. 2, thus locating the position of the point 6′ of the pattern.

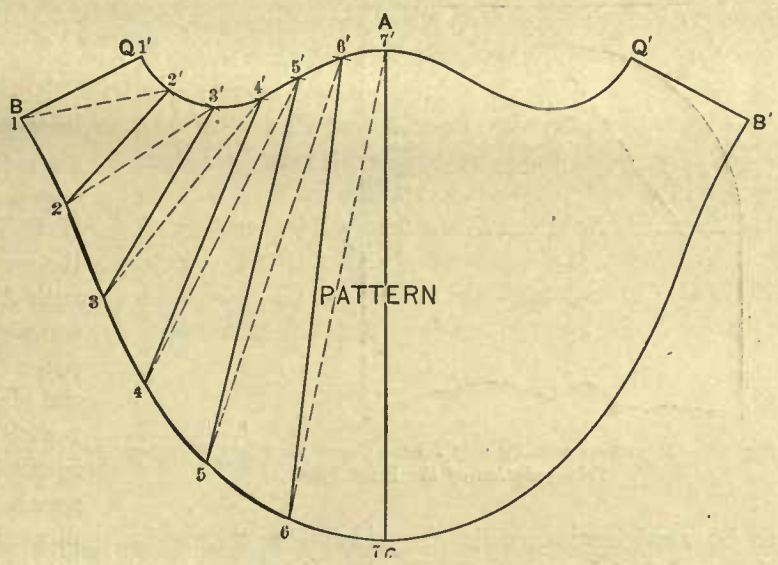


Fig. 659.—Pattern of Shape Shown in Fig. 657.

So continue to use the spaces of the plan, the lengths of the dotted lines of the diagram of triangles, the spaces in the profile and the lengths of the solid lines of the diagram of triangles in the order named until all have been used and the pattern is complete. Lines traced through the numbered points obtained, as

shown from C to B and from A to Q, will form the outlines of the pattern for half the article. The other half, A Q′ B′ C, can be obtained by any means of duplication most convenient.

PROBLEM 202.

Pattern for the Lining of the Head of a Bathtub.

In Fig. 660 are shown a plan and side and end views of the head of a bathtub or the lining of a tub the body of which is constructed of wood. The end view shows the bottom corners of the tub to be rounded, as shown at C¹ G¹ and B¹ F¹; the plan shows the head to be semicircular, while the side view shows that the junction between the head and the sides is made on the vertical line B² E². It will thus be seen that the conditions here given are the same as in the previous problem—viz., an irregular flaring piece forming a transition between two quarter circles (instead of complete circles as in the previous problem) lying in planes at right angles to each other.

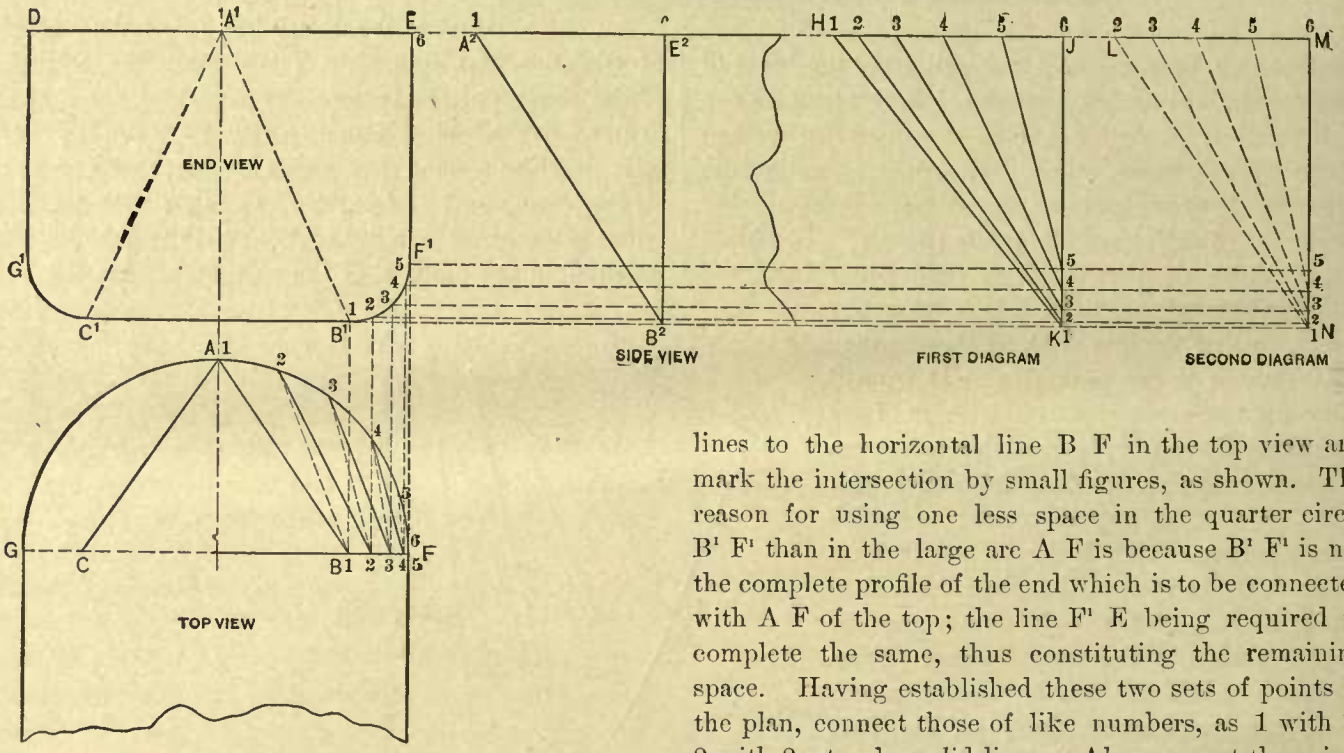


Fig. 660.—Elevations and Plan of Lining for a Bathtub, Showing Triangulation of the Head Piece.

Divide the quarter circle A F of the top view into any convenient number of equal spaces, as shown by the small figures. In like manner divide the quarter circle B¹ F¹ of the end view into the same number of equal spaces, less one, as also indicated by the small figures. From the points thus established in B¹ F¹ carry lines to the horizontal line B F in the top view and mark the intersection by small figures, as shown. The reason for using one less space in the quarter circle B¹ F¹ than in the large arc A F is because B¹ F¹ is not the complete profile of the end which is to be connected with A F of the top; the line F¹ E being required to complete the same, thus constituting the remaining space. Having established these two sets of points in the plan, connect those of like numbers, as 1 with 1, 2 with 2, etc., by solid lines. Also connect the points in the line of the top with those of the next lower number in the base, as 2 with 1, 3 with 2, etc., as indicated by the dotted lines. These solid and dotted lines form the bases of the two sets of triangles shown in the diagrams at the right, from which the correct measurements across the pattern are to be obtained.

To construct these diagrams extend A² E² of the side indefinitely to the right, as shown. At any convenient points, as J and M, drop the perpendiculars J K and M N. From the points established in the quarter circle B¹ F¹ carry lines horizontally to the right, cut-

ting the two perpendiculars, as shown by the small figures above K and N. From J, upon J H, set off the space J 1, equal to the line 1 1 of the plan or top view, and from the point 1 thus established draw the hypothenuse of the triangle, terminating in the point 1 of the line J K. In like manner set off from J, upon J H, the length 2 2 of the top view, also 3 3, 4 4 and 5 5, and from the points thus established draw lines to points of corresponding designation in the line J K, all as shown. By this means triangles have been constructed the hypothenuses of which represent measurements on the surface of the finished article, taken on lines corresponding to the solid lines of the top view.

In like manner construct the second diagram of triangles shown at the extreme right, setting off from

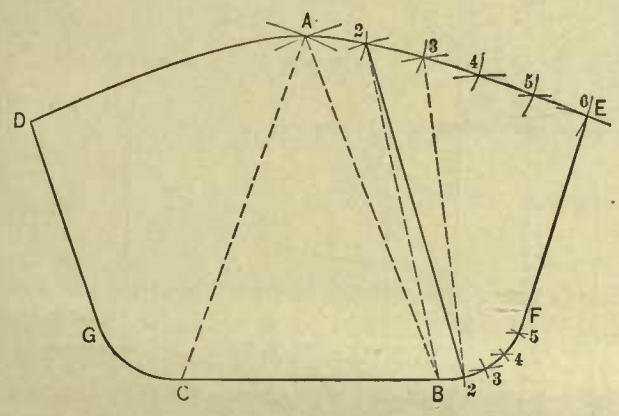


Fig. 661.—Pattern of Head Piece Shown in Fig. 660.

M distances equal to the length of the dotted diagonal lines in the top view, and connecting the points thus established with points of next lower number in the line M N. Then the hypothenuses of this set of triangles will give the lengths corresponding to measurements on the dotted lines of the plan or top view.

Having now obtained all the necessary measurements, the pattern may be developed as shown in Fig. 661. The central portion of the pattern will correspond to A' C' B' of the end view, it being simply a flat triangular piece of metal. Therefore draw any horizontal line, as C B, equal in length to C B or C' B' of Fig. 660. Take the space 1 1 of the first diagrams of the triangles as radius, and from C and B, respectively, as centers, strike arcs which will intersect at A. From A as center, with 1 2 of the outer line of the plan as radius, describe a small arc. From B as center, with 1 2 of the second diagrams of triangles as radius, intersect the arc as shown, thus establishing the point 2 in the upper curve of the pattern. Then from B as center, with 1 2 of the arc B' F' of the end view as radius, describe another small arc, and from 2 of the upper edge of the pattern as center, with 2 2 of the first diagram of triangles as radius, intersect it as shown, thus establishing point 2 in the lower line of the pattern. Proceed in this way, using alternately the stretchout of the top of the tub, as indicated by the plan view, with the hypothenuses of the second diagram of triangles to establish the points in the upper curve of the pattern, and the stretchout of the quarter circle shown in the end view with the hypothenuses of the first diagram of triangles to establish the points in the lower line of the pattern, until the points 6 and 5, or E and F, are reached. Connect E and F by a straight line and through the points from A to E and from B to F trace lines, as shown; then A E F B will be the pattern for one of the corners of the head, a duplicate of which may be reversed and transferred to the other side of the pattern, as shown by A D G C, thus completing the entire pattern of the head in one piece.

PROBLEM 203.

The Pattern for a Boss to Fit Around a Faucet.

In Fig. 662 are shown two views of a boss such as is used for fastening a faucet into the side of a large can; the curvature of the body of the can being represented by the line A D B. For convenience in demonstration, what would be properly considered the front view of the article is here called the top view, the other view being considered as the side. Let H L and K N represent its desired length and width of base or part to fit against the body of the can, and P R O the circle of the top to fit around the neck of the faucet. Also let D E be its required projection from the can. Through E draw Y Z parallel to H L,

the long diameter of the base. From P and O drop lines at right angles to H L, cutting Y Z in the points Y and Z, also from H and L drop lines cutting A D B, and connect the points thus obtained with Y and Z, as shown, thus completing the side view.

Commence by dividing one-quarter of the plan of the base K H into any convenient number of spaces, as shown by points 1, 2, 3, etc. For greater accuracy these spaces may be made shorter as they approach the ends of the base, where the line has more curve than near the middle. Having established the points 0, 1, 2, 3, etc., in K H, draw a line from each of them to the center of the plan M. By this means the quarter of the circle representing the top of the article, measurements, as shown at the right of C E, the hypothenuses of which will represent the real distances between the required points.

Therefore from the points established in H K drop lines vertically cutting the section line A D B, as indicated, then carry lines from the points on A D horizontally till they cut the line C E and continue them indefinitely to the right. The points at which these lines cross the center line E C will represent the hights of the several triangles. On these horizontal lines, measuring from the center line C E, which is assumed as the common perpendicular for all the triangles, set off the bases of the several triangles, transferring the distances from the plan. From the points

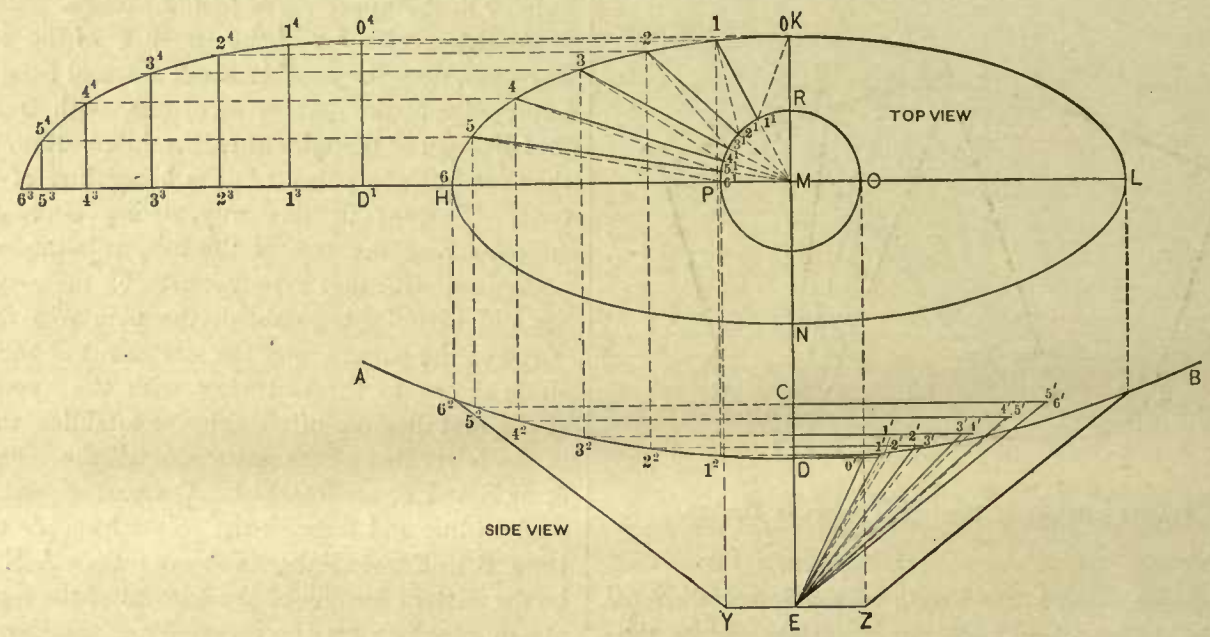


Fig. 662.—Top and Side View of Boss, Showing System of Triangulation.

and shown in the diagram by P R, will be divided in the same manner or proportionately to the plan of the base, all as shown by points 1', 2', 3', etc. It will be seen that these lines divide the surface of the boss into a number of four-sided figures, each of which must now be redivided diagonally so as to form triangles. Therefore connect 0 with 1', 1 with 2', etc., by means of dotted lines, as shown. These solid and dotted lines drawn across the top view represent the horizontal distances between the points given, while the vertical distances between the same can be measured on lines parallel to C E; hence it will be necessary to construct a series of triangles from these thus established draw lines to E, which will give the hypothenuses of the several triangles. For example, on the line drawn from the point 5^2, in A D B, measuring from C, set off a distance equal to 5' 5 and also a distance equal to 6' 5 in the top view. The difference between these two is so small as to be imperceptible in a drawing to so small a scale as this. In like manner, on the line drawn from 4^2 set off a distance equal to the length of the diagonal lines 4 5' and 4 4' in the top view, and in the same manner on the line drawn through 3^2 set off the distance equal to 3 4' in the top view and also 3 3'. Then, as before remarked, lines drawn from the points thus established

in the horizontal lines toward E will be the hypothenuses of the several triangles corresponding to sections represented by the diagonal lines in the top view.

In view of the fact that the base of the boss is curved as shown by A D it will be noticed that the measurements from K to H in the top view do not represent the real distances, because the distance H M is less than the distance A D. In case extreme accuracy is required it will therefore be necessary to develop an extended section on the base line A D, which may be done as follows: Extend the line M H

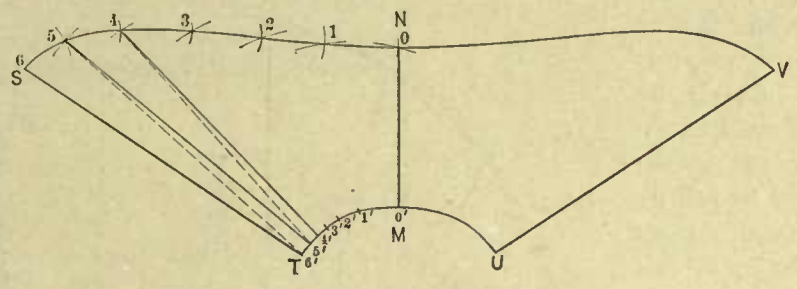


Fig. 663.—Pattern for Boss.

of the top view, as shown at the left, upon which place a correct stretchout of A D; that is, make $D^1\ 1^3$ equal to $D\ 1^2$, $1^3\ 2^3$ equal to $1^2\ 2^2$, etc., and through each of the points thus obtained draw measuring lines at right angles to D^1 M. Place the T-square parallel to H M, and, bringing it successively against the points in the line K H, drop lines into the measuring lines of corresponding number, as shown by 0^4, 1^4, 2^4, etc. Then will the distances $0^4\ 1^4$, $1^4\ 2^4$, etc., be the correct distances to be used in developing the pattern instead of the distances 0 1, 1 2, etc.

The pattern may now be developed as shown in Fig. 663. Lay off the line S T, in length equal to the required width of the pattern on one end, as shown by $Y\ 6^2$ in Fig. 662. With these two points established proceed to obtain other points in both lines of the pattern by striking arcs with radii equal to the spaces established in the plan of both base and top of the article and to the hypothenuses of the triangles already described. Thus, from S as center, with radius equal to the distance $6^3\ 5^4$ of the stretchout of the base, describe a short arc, as shown at 5 in the pattern. Then from T as center, with radius equal to E 6′ of the triangles, intersect it by a second arc, as shown. From T as center, with radius equal to $6^1\ 5^1$ of the plan of the top of the article, describe a small arc, as shown, and from 5 of pattern as center, and radius equal to E 5′ of the triangles, intersect it by another arc, thus determining the second point in the top. Proceed in this manner, adding one triangle after another in the order in which they occur in the top view, using the spaces of the plan of top and of the stretchout of the bottom and the hypotheneuses of the triangles as above described. Lines traced through the points thus obtained, as shown from S to N and from T to M, will give the pattern of one-quarter. This can be duplicated as often as is necessary to make the entire pattern in one piece, or to produce it in halves, as shown.

PROBLEM 204.

Patterns for a Ship Ventilator Having a Round Base and an Elliptical Mouth.

In Fig. 664 are presented the front and side elevations of a ship ventilator of a style in common use. $A^1\ B^1$ shows the section or plan of its lower piece A E F B, as well as of the pipe to which it is joined, while R O S P is the shape of its mouth, or a section upon the line C D. The curves E C and F D connecting the two ends of the ventilator and forming the general outlines of the same may be drawn at the discretion of the designer. As the ventilator is constructed after the manner of an elbow, it may be divided into as

many sections or pieces as desired. Therefore divide the curved lines E C and F D into the same number of spaces, and connect opposite points by straight lines, as shown by G H, K L and M N. These lines should be so drawn as to produce a general equality in the appearance of the different pieces without reference to equality in the spaces in either outline.

The next step is to establish a profile or section upon each one of these lines. These profiles can be drawn arbitrarily, but each should be so proportioned that the series will form a gradual transition from the circle A¹ B¹ to the ellipse R O S P. All the profiles will, therefore, be elliptical, those nearer the mouth being more elongated than those nearer the base or neck. Since the lower piece is cylindrical and is cut obliquely by E F, the section at E F must necessarily be a true ellipse and can be developed by a method frequently explained in connection with various problems in the first section of this chapter, and as also explained in Geometrical Problem 68 on page 61. Of the remaining sections, their major axes are, of course, equal to the lengths of the lines G H, K L and M N, and their minor axes may be determined by any method most convenient, or in the following manner: Draw R U and S V, representing a front view of the curved lines passing through the points *n*, *m*, *k*, *g* and *e* of the side view. From the points *g*, *k* and *m* project lines horizontally across to the front view, cutting the lines R U and S V and the center line O T. Then *f l*, *d o* and *b c* will be respectively one-half the minor axes of the sections above referred to. With the major and minor axes of the several sections given, they may be drawn by any method producing a true ellipse, or in case the mouth has been drawn by means of arcs of circles the other sections may be drawn in the same manner.

Each of the several pieces of which the ventilator is composed (except the lower piece) becomes, as will be seen, a transition piece between two elliptical curves not lying in the same plane, and in that respect is the same as the form shown in Problem 191. The pattern for each piece must, therefore, be obtained at a separate operation, that for the piece M N D C only being given. To avoid confusion of lines a duplicate of it is transferred to the opposite side of the front elevation, as shown by W Y Z X. Drop points from Y and Z perpendicular to the center line O T of the elevation, thus locating the points M² and N². Make the distance *b*² *c* equal to *b c*. Then draw the ellipse M² *b*² N², which will be a front view of the section M N of the side elevation. On a line parallel with Y Z construct the section M¹ *b*¹ N¹, as follows: Let M¹ N¹ be equal to and opposite Y Z. Let the distance *c*¹ *b*¹ be equal to the distance *c b* of the section. With these points determined, draw through them the semi-ellipse M¹ *b*¹ N¹. Divide the sections M¹ *b*¹ N¹ and O S P into the same number of equal parts, as indicated by the small figures in the engraving. Drop the points 1, 2, 3, 4, etc., on to and perpendicular to the line Y Z; thence carry them perpendicular to the center line O P of the front elevation, cutting the section M² *b*² N² in the points 1², 2², 3², etc., thus dividing it into the same number of spaces as were given to the original section M¹ *b*¹ N¹. Next connect the points of like numbers in the two sections of the front elevation by solid lines, thus: Connect 2¹ with 2², 3¹ with 3², 4¹ with 4², etc.; also connect the points 2¹ with 1², 3¹ with 2², 4¹ with 3²,

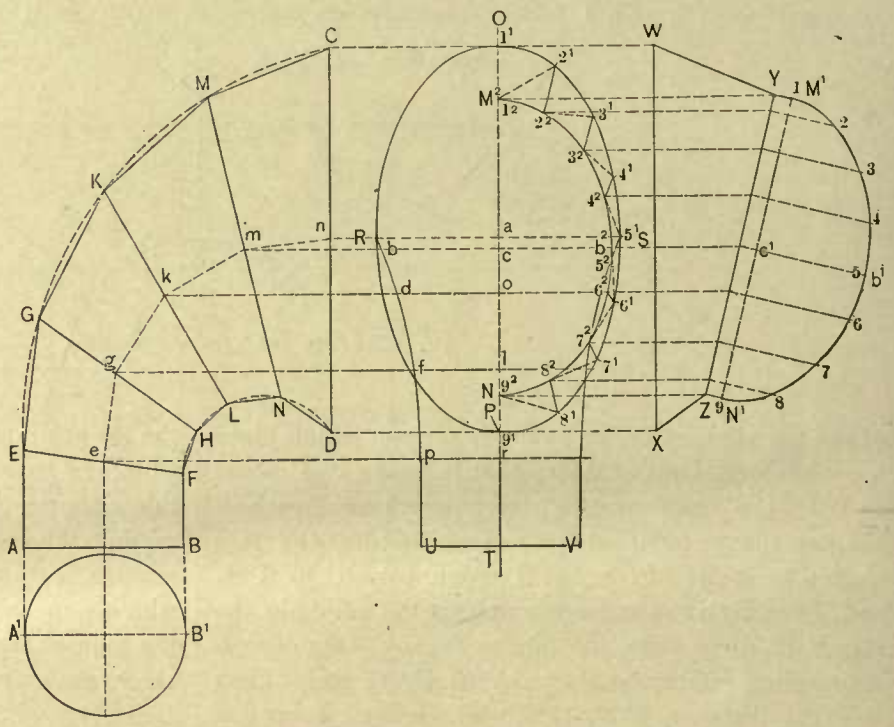


Fig. 664.—Elevations and Sections of a Ship Ventilator.

etc., by dotted lines, all as shown in the engraving. These lines represent the bases of right angled triangles, whose altitudes may be measured on the horizontal lines cutting the lines W X and Y Z.

The next step, therefore, is to construct diagrams of these triangles, as shown at A and B of Fig. 665. Draw any two horizontal lines as bases of the triangles, and erect the perpendiculars E C and F D. On both E C and F D set off the various hights of the triangles, measured as above stated and as indicated by the points 1, 2, 3, 4, etc. Next set off the length of the bases of the triangles as follows: In diagram A, let C 1 equal the distance $1'\ 1^2$ of Fig. 664; make C 2 equal to $2'\ 2^2$ and C 3 equal to $3'\ 3^2$, etc. Connect the points in the vertical line with the points in the horizontal line of the same number, thus obtaining

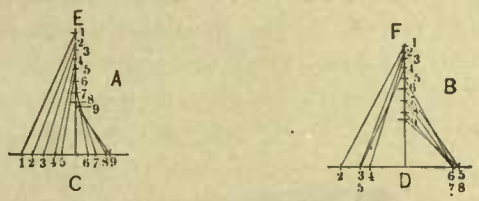


Fig. 665.—Diagrams of Triangles.

hypothenuses of the triangles, or the true distance between the points $1'\ 1^2$, $2'\ 2^2$, etc., of the elevation. In diagram B, let the distances D 2, D 3, D 4, etc., represent the distances $1^2\ 2'$, $2^2\ 3'$, etc., of the elevation. Having located these points, connect 1 in the vertical line with 2 in the base; also 2 in the vertical line with 3 in the base, and proceed in this manner for the other points. This will give the hypothenuses of the triangles, whose bases are $1^2\ 2'$, $2^2\ 3'$, etc., in the elevation.

Having thus obtained the dimensions of the various triangles composing the envelope of the first section of the ventilator, proceed to develop the pattern for it, as shown in Fig. 666. On any straight line, as C M, set off a distance equal to 1 1 in diagram A. From C as center, with radius equal to $1'\ 2'$ of the elevation, Fig. 664, draw an arc, which cut by another arc drawn from M as center, with radius equal to 1 2 of diagram B, thus establishing the point 2. From 2 as center, with radius equal to 2 2, diagram A, draw an arc, which cut with another arc drawn from $1'$ as center, with radius equal to 1 2 of the elevation, thus establishing the point $2'$. Proceed in this manner, next locating the point 3, then the point $3'$; next the point 4, and then $4'$, etc. It will be noticed that, after

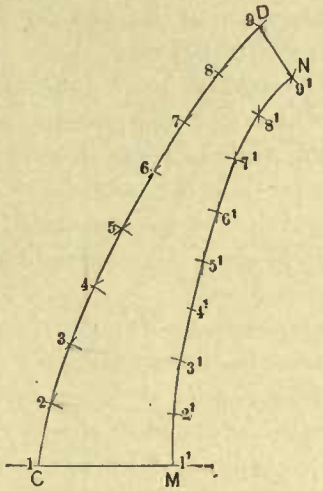


Fig. 666.—Pattern of First Section of Ship Ventilator.

passing points 6 and $6'$, $7'$ is obtained before 7. This is for the sake of accuracy, as it will be seen by inspection of the elevation that the distance $7^2\ 6'$ is less, and therefore more accurately measured in the elevation, than the distance from 6^2 to $7'$. Having thus located the points 1, 2, 3, etc., $1'$, $2'$, $3'$, etc., trace the lines C D and N M, and connect D with N, as indicated in Fig. 666. Then D N M C will be the pattern for one-half the section M N D C of the elevation.

The pattern of the section E A B F will be the same as that for the corresponding piece in an ordinary elbow, and, therefore, need not be specially explained here.

PROBLEM 205.

Patterns for the Junction of a Large Pipe with the Elbows of Two Smaller Pipes of the Same Diameter.

The elbows of the smaller pipes in the problem here presented are such as would, if each were completed independently of the other, form six-piece elbows. The junction between the two elbows occurs between the fifth pieces, which pieces unite to form the transition from the smaller diameters of the elbows to the diameter of the larger pipe, or sixth piece. A pictorial representation of the finished work is shown in Fig. 667, in which, however, the upper section, or larger pipe, is omitted to more fully show the shape and junction of the transition pieces. A front view or elevation of the various parts is shown in Fig. 668. The side view given in Fig. 669 shows more fully the amount of lateral flare of the transition piece necessary to form a union between the varying diameters of the larger and smaller pipes.

The drawing of that portion of the elbows in the smaller pipes from the horizontal parts up to the line *a h t* in Fig. 668 is exactly the same as that employed in drawing a six-piece elbow. The piece A G *h a*, occupying the place of what would otherwise be the fifth piece of the elbow, becomes in this case an irregular shape, the lower end or opening, *a h*, of which is nearly circular while its upper end, A G, is a perfect semicircle. This piece unites with its mate G D *t h* on the line G *h*, thus forming the complete circle at A D, a plan of which is shown immediately below the elevation. The relative proportion between the diameters of the larger and smaller pipes is such that the junction between the elbows is carried somewhat below the fifth pieces, mitering the fourth pieces for a short distance, as shown from *h* to L. The method of cutting the lower parts of the elbow, however, is the same as that employed in all elbow patterns where the pipe is of a uniform diameter throughout, numerous examples of which are given in Section 1 of this chapter, to which the reader is referred.

As the section or profile of all the parts forming the elbow is a perfect circle when taken at right angles to the sides of the pipe, as at Q F or M N, it will be seen that a section on the line *a h* will be somewhat elliptical; it will therefore be necessary to obtain a correct drawing of this section from which to obtain the stretchout of the lower end of the piece A G *h a*, with which it joins, and also a drawing of it as it will appear in plan. Therefore between two parallel lines drawn from M and N at right angles to M N construct a profile or section, as shown below at the left, which divide into any convenient number of equal spaces, as shown by the small letters *a*, *b*, *c*, etc. From each of these points carry lines back to M N at right angles to the same, and continue them in either direction till they cut the miter line *a n* of the elevation, as shown by the small letters, and the center line *a n* of the section. From the points in *a n* of the elevation draw lines at right angles to the same indefinitely, as shown above the elevation, across which at any convenient point draw a line, as B^1 C^1, at right angles to them. From B^1 C^1 set off on the lines last drawn distances equal to the distances from the circumference to the diameter on corresponding lines in the section below, all as shown by a^2, b^2, c^2, etc. A line traced through these points will be the correct section on the miter line *a n*. It will be noticed that the section has not been carried further than the point h^2, the balance of the curve not being required by reason of its intersection with the corresponding piece in the other elbow.

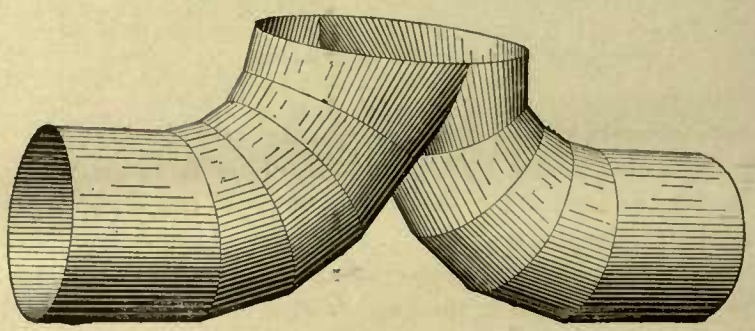


Fig. 667.—Perspective View of the Junction of a Large Pipe with the Elbows of Two Smaller Pipes.

Below the elevation and in line with the same, as shown by the center line G T, is drawn the plan of the larger pipe A B C D. It will be necessary to add to this the plan of the curve on the line *a h* of the elevation, in order that the horizontal distances between the points assumed in the two curves may be accurately measured. Therefore from the points on the miter line *a h* drop lines vertically through the plan, cutting the transverse center line X Y. From X Y set off distances on these several lines equal to the distances

of corresponding points from the line *a n* of the original section, as shown by *a'*, *b'*, etc., from X to S. A line traced through these points will give the correct position of the intersection of the smaller pipe as seen from above. This entire line is shown in the plan, although the part from S to Z will not be required, for the reason given above. An inspection of the plan will show that the side of the plan from V T to the right would be an exact duplicate of the left side if it were completed, and that therefore the plan consists of four symmetrical quarters, one of which, X R T, is completely shown in the plan. Hence the pattern for this quarter will suffice by duplication for the entire transition piece.

Divide the quarter of the plan of the larger pipe P T, adjacent to the curve X S, into the same number of equal spaces as are found in the inner curve from X to S, as shown by the small figures 1, 2, 3, etc. Connect corresponding points in the two lines as shown by the solid lines *h'* 8, *g'* 7, *f'* 6, etc. Next subdivide the four-sided figures thus obtained by their shortest diagonal, as shown by the dotted lines *g'* 8, *f'* 7, etc. These solid and dotted lines across the plan represent the bases of a series of right angled triangles whose altitudes can easily be obtained from the elevation, and whose hypothenuses when obtained will give correct distances across the finished piece between points connected on the plan. These lines have also been drawn across the elevation from corresponding points in the same for illustrative purposes, but such an operation is not necessary to obtain the pattern. Neither is the side view shown in Fig. 669 necessary to the work, but is here introduced merely to assist the student in forming a more perfect conception of the operations described. From the points *a*, *b*, *c*, etc. on the miter line *a h* of the elevation carry lines horizontally across, cutting the vertical line G L, as shown by the points from *s* to *h*. The distances of these points from G will then represent the vertical distances of corresponding points in X S of the plan from the plane of upper base of the transition piece shown by A D of the elevation and V P T of the plan.

To obtain the hypothenuses of the various triangles above alluded to, or in other words, the true

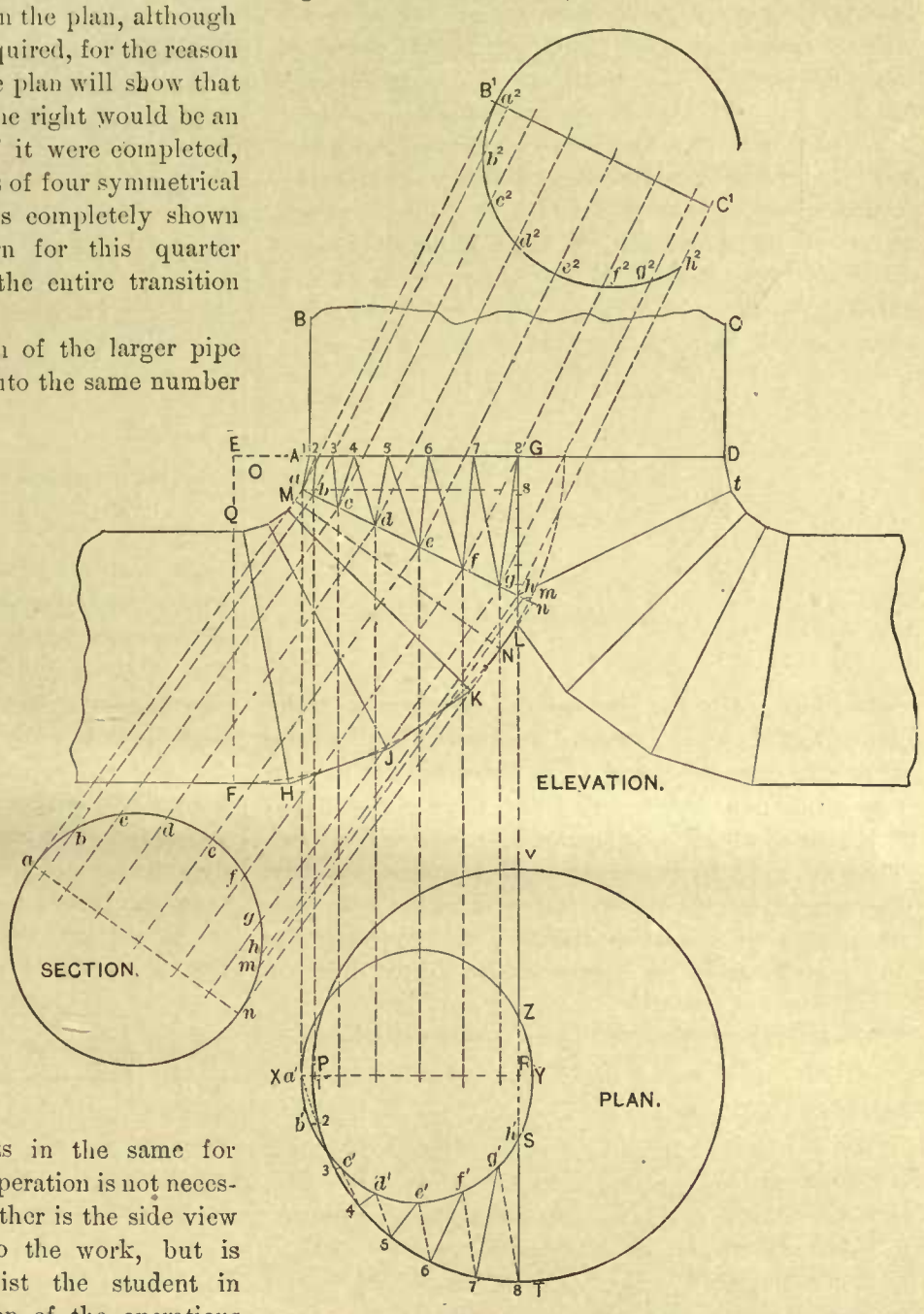


Fig. 668.—Front Elevation, Plan and Sections, Showing Method of Triangulation.

lengths of the lines dividing the surface, as shown in the two elevations and plan, it will be necessary to construct a series of diagrams, as shown in Fig. 670. Therefore draw any two lines, as *h* 8 and *h h'*, at right

angles to each other; make h 8 equal to h' 8 of the plan, Fig. 668, and $h\ h'$ equal to h 8 of the elevation, and draw h' 8. Next draw any two lines, as g 8 and $g\ g'$, at right angles to each other, making g 8 equal to the

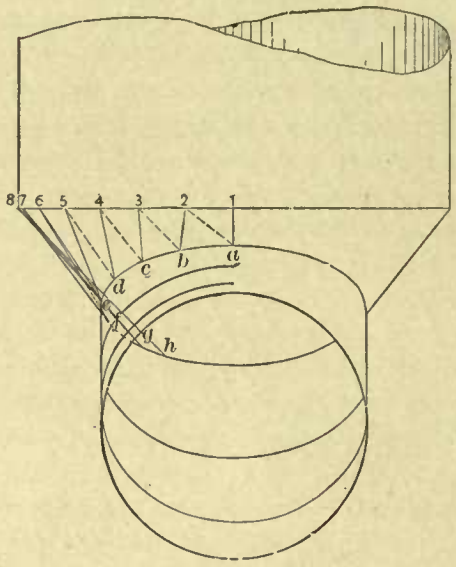


Fig. 669.—Side Elevation.

dotted line g' 8 of the plan and g 7 equal to the solid line g' 7 of the plan. Make $g\ g'$ equal to the distance of point g from the line A D as measured by its corresponding point on the line L G. Draw g' 8 and g' 7. So continue till all the triangles have been constructed. Then the solid hypothenuses will represent the true distances across the pattern indicated by the solid lines of the plan and elevations, and the dotted hypothenuses the true distances on corresponding dotted lines in those views. In describing the pattern, work can be begun at either end of the pattern most convenient.

Draw any straight line, as 1 a of Fig. 671, which make equal to the line 1 a' of the diagram of triangles, Fig. 670. From 1 as a center, with a radius equal to 1 2 of the plan, describe a small arc, which intersect with another small arc drawn from a as center, with a radius equal to a' 2 of the diagram of triangles, thus locating the point 2 of the pattern. From point 2 as a center, with a radius equal to b' 2 of the diagram of triangles, describe a small arc, which intersect with another small arc struck from a of the pattern as center, with a radius equal to $a^2\ b^2$ of the section on line $a\ h$ of elevation shown above, thus establishing the position of the point b of the pattern. Proceed in this manner, using the spaces in P T in the plan of the larger pipe to form the upper edge of the pattern and the spaces from the section B^1 C^1 to form the lower edge of the pattern, measuring the distances between the same by the alternate use of the solid and dotted hypothenuses of corresponding number and letter taken from the diagram of triangles in Fig. 670. A line traced through the two series of points and a straight line from 8 to h will complete the pattern for one-quarter of the transition piece required. The remaining three-quarters can be obtained by any means of duplication most convenient.

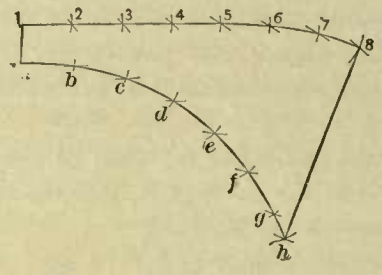


Fig. 671.—Pattern for One-Quarter of Connecting Piece.

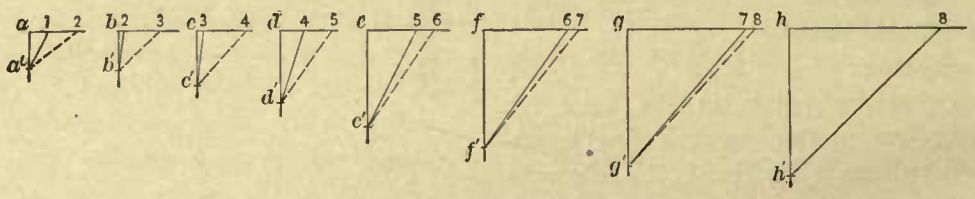


Fig. 670.—Diagram of Triangles.

PROBLEM 206.

The Patterns for a Right Angle, Two-Piece Elbow, One End of Which is Round and the Other Elliptical.

In Fig. 672, let A G C B H D represent the elevation of elbow, A F D the half profile of elliptical end and C E B the half profile of round end. The first step will be to establish a section on the miter line G H. Since the width at A D, one-half of which is shown by K F, is greater than J E, one-half the width at C B, it is proper that the width at L should be a medium between the two. Therefore from K, on K F, set off the distance J E, as indicated by K *m*. Bisect F *m* in *n*, and take K *n* as the width at L. The section at G H will then be an ellipse, of which G H is the major axis and K *n* one-half of the minor axis.

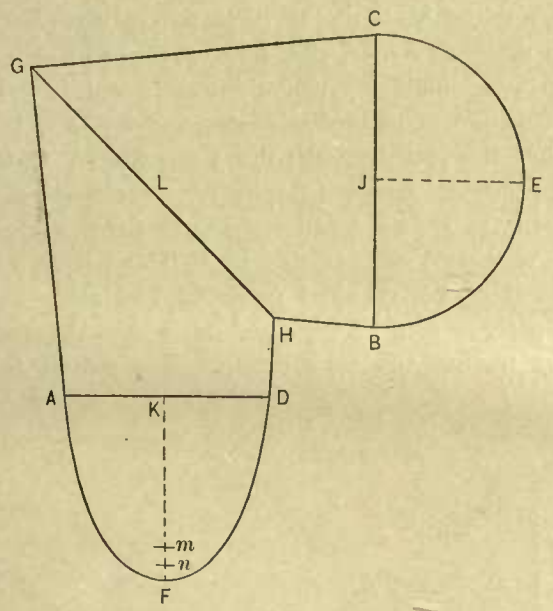


Fig. 672.—Elevation of Elbow, with Half Profiles of the Two Ends.

In Fig. 673, A G H D is a duplicate of the part bearing the same letters in Fig. 672. Against A D is placed a half profile, A F D, of the elliptical end, while against G H is placed one-half of the elliptical section, constructed as above described and as shown by G L H. Divide G L H into any convenient number of equal parts, and from the points thus obtained drop perpendiculars cutting G H, as shown. Also divide A F D into the same number of parts, and from the points thus obtained drop perpendiculars cutting A D. Connect the points in A D with those in G H, as indicated by the solid and dotted lines.

The next step is to construct sections on each of the solid and dotted lines drawn across the elevation by means of which to obtain the true distances between the points in A D and those in G H as though measured upon the finished article. In Fig. 674 is shown a diagram containing sections upon the solid lines, which is constructed in the following manner: Draw any two lines, as M N and M P, at right angles to each other. Upon M N set off the hights of the several points in the profile A F D; thus make M 13, M 12, M 11, etc., respectively equal to *k* 13, *j* 12, *h* 11, etc., of Fig. 673. Upon M P set off from M the lengths

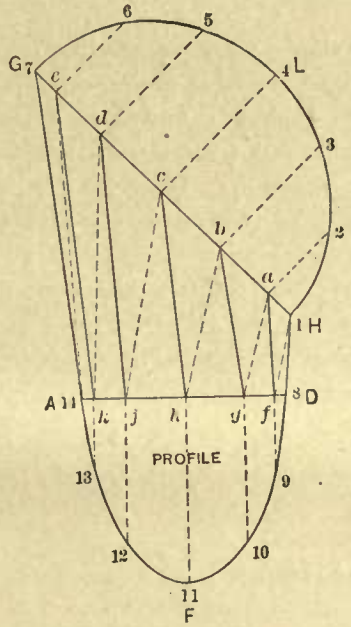


Fig. 673.—Elevation of Lower Piece of Elbow, Showing Method of Triangulation.

of the several solid lines of the elevation; thus make M *a*, M *b*, etc., respectively equal to *f a*, *g b*, etc., of Fig. 673, and at the points *a*, *b*, *c*, etc., thus obtained, erect perpendiculars, each equal in hight to the hight of the corresponding point in the profile G L H of Fig. 673 from the line G H. Thus make *a* 2, *b* 3, etc., of the diagram respectively equal to *a* 2, *b* 3, etc., of Fig. 673, and from the points 2, 3, 4, etc., thus obtained, draw solid lines to points 9, 10, 11, etc., in the line M N, all as shown. Then the distances 9 2, 10 3, 11 4, etc., will be the true lengths represented by corresponding solid lines drawn across the elevation.

The true distances represented by the dotted lines drawn across the elevation are obtained in the same manner by means of the diagram shown in Fig. 675. R S is drawn at right angles to R T and upon it are set off the hights of the points in A F D the same as in M N of Fig. 674. Upon R T set off from R the lengths of the several dotted lines drawn across the

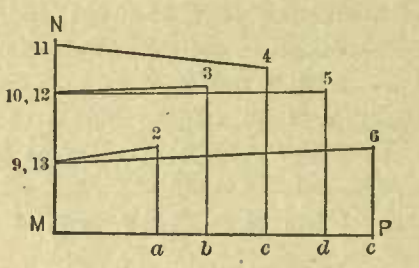


Fig. 674.—Diagram of Sections Upon Solid Lines of Fig. 673.

elevation, as shown by corresponding letters, and from the points thus obtained erect perpendiculars also as in Fig. 674. Finally connect by dotted lines such points as correspond with those connected by dotted lines in the elevation. Thus from 9 in R S draw a line to point 1 in the base line, corresponding to the line *f* 1 of the elevation, Fig. 673. Lines from 10 to 2 and from 11 to 3 of the diagram will correspond respectively to *g a* and *h b* of Fig. 673.

To develop the pattern from the dimensions now obtained proceed as follows: At any convenient place

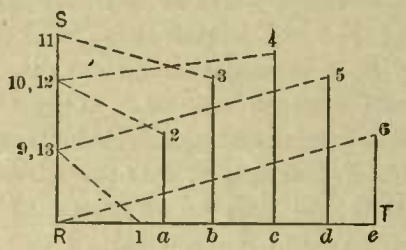


Fig. 675.—Diagram of Sections Upon Dotted Lines of Fig. 673.

draw the straight line H D in Fig. 676, in length equal to H D of Fig. 673. From H of pattern as center, with radius 1 9 of Fig. 675, describe an arc, which intersect by a second arc struck from D as center, with radius D 9 of profile, thus establishing the point 9 of pattern. Then with radius H 2 of G L H, Fig. 673, from H of pattern as center, describe an arc, which cut with another arc struck from point 9 of pattern as center, and 9 2 of Fig. 674 as radius, thus establishing point 2 of pattern. With point 2 of pattern as center, and 2 10 of Fig. 675 as radius, describe an arc, which intersect with another arc struck from point 9 of pattern as center, and 9 10 of profile as radius, thus establishing point 10 of pattern. With point 10 of pattern as center, and 10 3 of Fig. 674 as radius, describe a small arc, which intersect with one struck from point 2 of pattern as center, and 2 3 of G L H as radius, thus establishing point 3 of pattern. Continue this process, locating in turn the remaining points in pattern, as shown. Lines drawn through the points thus obtained, as indicated by G H and D A, will be one-half of the required pattern. The other half of the pattern can be obtained in a similar manner, or by tracing and transferring. The pattern for the

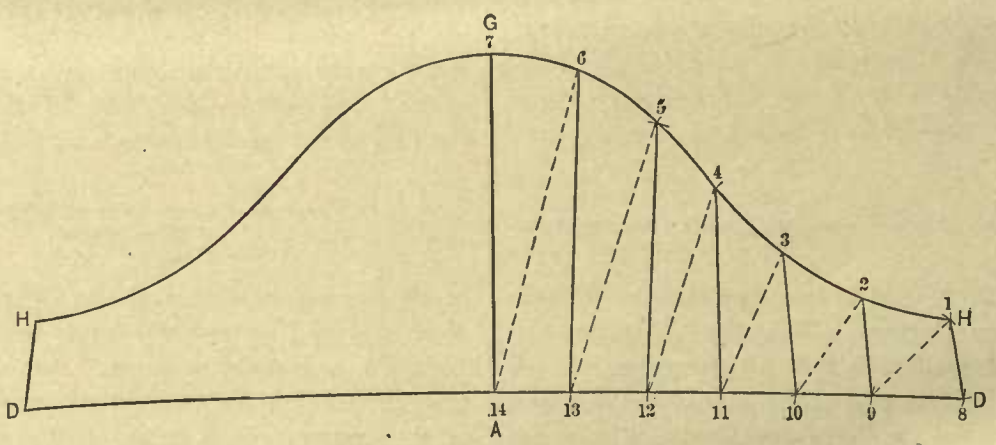


Fig. 676.—Pattern for Lower Piece of Elbow.

other part of elbow, as shown in Fig. 672 by G C B H, can be obtained by the same method. The shape G L H of Fig. 673 is to be drawn to the left of the miter line G H, and the operation continued, using the same process, as shown in Figs. 674, 675 and 676.

PROBLEM 207.

The Pattern for a Y Consisting of Two Tapering Pipes Joining a Larger Pipe at an Angle.

In Fig. 677, B C D E represents the elevation of a portion of the larger pipe and C′ K D′ L its profile. This pipe is cut off square at its lower end, with which the branches of the Y are to be joined. A B O H J and G H O E F are the elevations of the two similar branches joining each other from H to O, and the larger

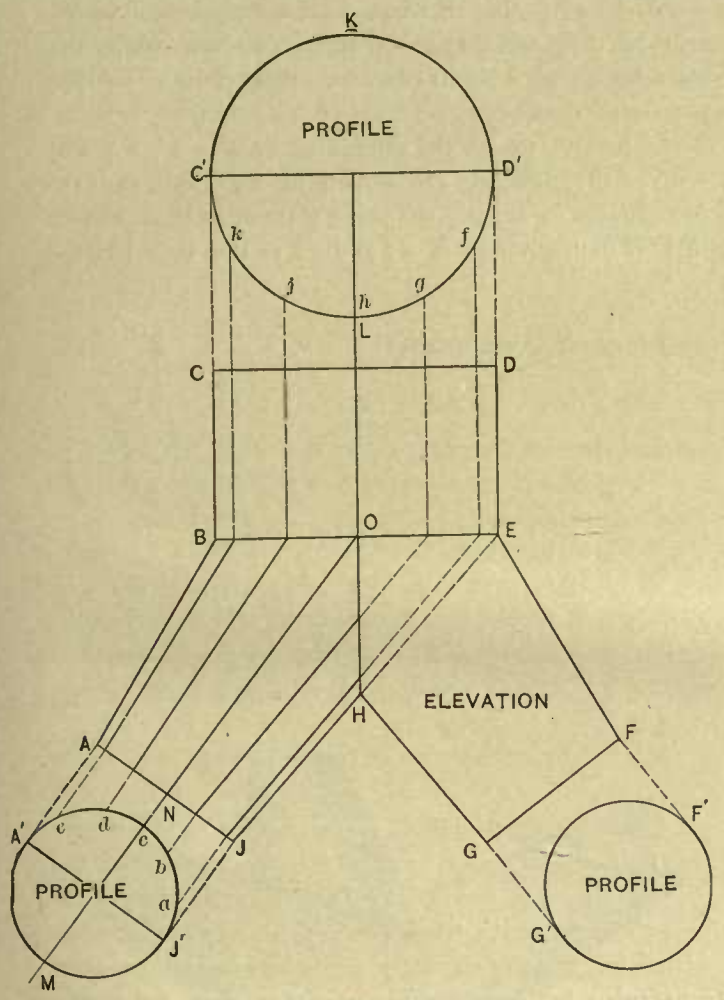


Fig. 677.—Elevation and Profiles of Y *with Tapering Branches.*

pipe on the line B E. A′ N J′ M is the profile of one of the tapering branches at its smaller end.

Since the article consists of two symmetrical halves when divided from end to end on the lines A′ J′ or C′ D′ of the profiles, and since the two branches are alike, the pattern for one-half of one of the branches, as A B O H J, is all that is necessary.

The dividing surface A B O H J, lying as it were at the back of the half of the branch shown in elevation by the same letters, will then form a plane or base from which the hights or projection of all points in the surface of the branch piece can be measured.

As the branch piece A B O H J is an irregular tapering form, its surface must be divided into a series of measurable triangles before its pattern can be obtained. Therefore divide the half profile C′ L D′ into any convenient number of equal parts—in the present instance six, as shown by the small letters *f g h j k*—and from these points drop lines parallel with C B, cutting the line B E, as shown. In a similar manner divide the half profile A′ N J′ into the same number of equal

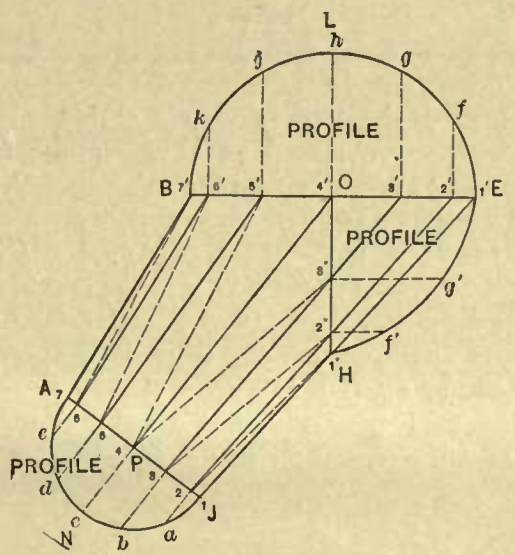


Fig. 678.—Elevation of One Branch of Y*, Showing Method of Triangulation.*

parts as was C′ L D′, as shown by the small letters *a b c d e*. From the points thus obtained carry lines parallel with J′ J, cutting A J. Connect the points in A J with those in B E, as shown.

To avoid a confusion of lines the subsequent operations are shown in Fig. 678, in which A B O H J is a duplicate of the piece bearing the same letters in Fig. 677. The profiles B L E and A N J are also duplicates of those shown in Fig. 677 and are for convenience here placed adjacent to the lines which they represent. B L of the upper profile then represents a section on the line B O, and A N J that upon the line A J, but the section on the line O H, the miter between the two branches, is as yet unknown. To obtain this it will be necessary to first obtain sections upon

the various lines drawn across the elevation from B E to A J in Fig. 678, or in other words, diagrams upon which the true lengths of those lines can be measured.

In the diagram of sections shown in Fig. 679

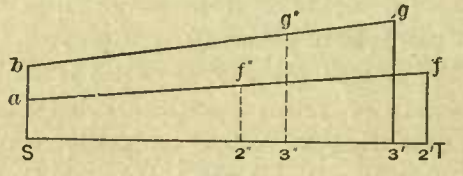


Fig. 679.

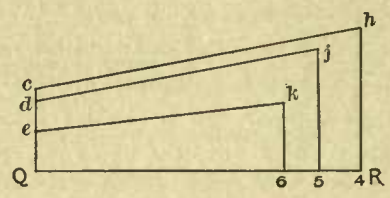


Fig. 680.

Diagrams of Sections Upon Solid Lines of the Elevation.

S T represents the dividing surface or base plane alluded to above and is made equal in length to 2 2′ of Fig. 678. At either extremity of this line erect the perpendiculars S *b* and T *f*, as shown. Make T *f* equal in hight to 2′ *f* of profile B L E, and upon S *b* set off from S the hight S *a*, equal to 2 *a* of the profile A N J, and draw the line *a f*. On S T, measuring from T, set off the distance 2′ 2″, and erect the perpendicular 2″ *f*″, cutting *a f* at *f*″. Then will *a f* represent the true distance between the points 2 and 2′ in Fig. 678, and *a f*″ will represent the true distance from 2 to 2″,

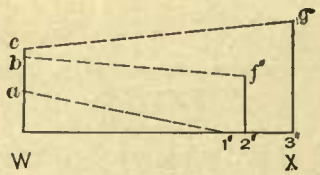


Fig. 681.

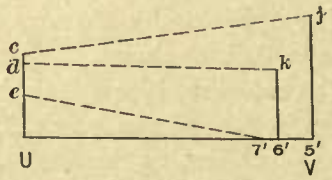


Fig. 682.

Diagrams of Sections Upon Dotted Lines of the Elevation.

while 2″ *f*″ will be the hight of the point 2″. In a similar manner set off from S, on S T, a distance equal to 3 3′ of Fig. 678 and erect the perpendicular 3′ *g*, equal in length to 3′ *g* of profile B L E. Make S *b* equal to 3 *b* of profile A N J and draw *b g*. From S set off on S T a distance equal to 3 3″ of Fig. 678 and erect the perpendicular 3″ *g*″, cutting *b g* at *g*″. Then will *b g* be equal to the true distance between 3 and 3′ of Fig. 678, *b g*″ will be the true distance from 3 to 3″ of Fig. 678 and 3″ *g*″ will be the hight of the point 3″. To construct the section on the line O H, at points 3″ and 2″ draw 3″ *g*′ and 2″ *f*′ at right angles to O H, making them respectively equal 3″ *g*″ and 2″ *f*″ of Fig. 679. As the profile B L E is a semicircle the hight of point 4′—that is, 4′ *h*—is equal to O E; therefore through the points E, *g*′, *f*′ and H draw the curve shown, which will be the true section on line O H, from which the stretchout can be taken for that portion of the pattern.

The sections on the remaining lines (4 4′, 5 5′ and 6 6′) of the elevation are shown in Fig. 680 and are constructed in exactly the same manner as those shown in Fig. 679, giving *c h*, *d j* and *e k* as the true lengths

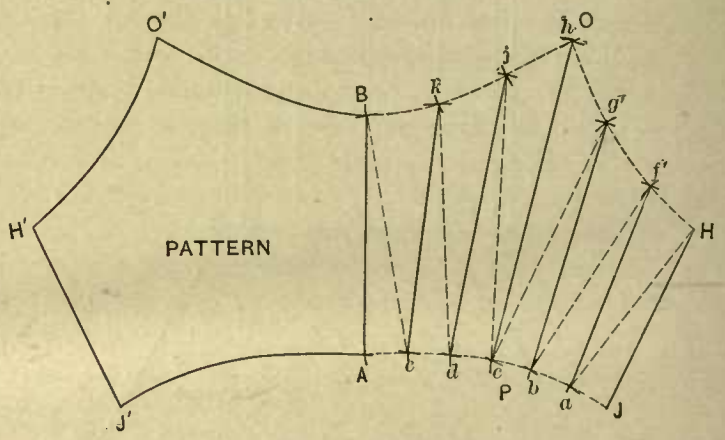


Fig. 683.—Pattern of Tapering Branch.

of those lines. Before the pattern can be developed the four-sided figures into which the surface of the branch pipe has been divided by the solid lines must be subdivided into triangular spaces, as shown by the dotted lines in the elevation. Sections upon these lines must also be constructed, in order that their true lengths can be obtained. These are shown in two groups in Figs. 681 and 682 and are constructed in a manner exactly similar to that described in connection with Fig. 679. They may be easily identified by correspondence between the figures on the base lines U V and W X and those of the elevation.

To describe the pattern proceed as follows: Draw any line, as J H in Fig. 683, in length equal to J H of Fig. 678. With J of pattern as center, and J′ *a* of smaller profile as radius, describe a small arc (*a*), which

cut with one struck from H of pattern as center, and 1″ *a* of Fig. 681 as radius, thus establishing the point *a* of pattern. With *a* of pattern as center, and *a f″* of Fig. 679 as radius, describe another small arc (*f′*), which intersect with one struck from H of pattern as center, and H *f′* of profile H E as radius, thus establishing the point *f* of pattern. In a similar manner, *a b* of pattern is struck with *a b* of profile as radius; *f′ b* of pattern with *f″ b* of Fig. 681 as radius; *b g′* of pattern with *b g″* of Fig. 679 as radius, and *f′ g′* of pattern with *f′ g′* of profile H E as radius; also, *b c* of pattern is struck with *b c* of profile as radius; *g′ c* of pattern with *g″ c* of Fig. 681 as radius; *g′ h* of pattern with *g′* E of profile as radius, and *c h* of pattern with *c h* of Fig. 680 as radius. Thus are the points established in O H J P of pattern.

B O P A of pattern corresponds with B O P A of elevation and is obtained in the same manner. The points in O B of pattern are derived from profile L B, as are the points in P A of pattern from N A of small profile. The lengths of solid lines in pattern are obtained from the diagram of sections in Fig. 680, as are those of the dotted lines from the diagram of sections in Fig. 682. Lines drawn through the points in B O H J P A, Fig. 683, will be the half pattern for A B O H J of elevation. The other half of pattern, as shown by A J′ H′ O′ B, can be obtained in a similar manner or by duplication.

PROBLEM 208.

Pattern for a Three-Pronged Fork With Tapering Branches.

In Fig. 684 is shown a pictorial representation of a fork, or crotch, consisting of three branches of equal size and taper; all uniting so as to form one round pipe.

In the plan, Fig. 685, A B C represents the base of article or size of the large pipe and B D E C G one of the tapering branches. The other branches are partly shown in plan by A G C S T and A U V B G.

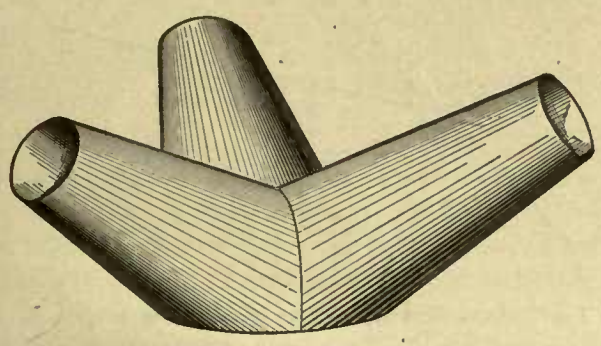


Fig. 684.—Perspective View of Three-Pronged Fork with Tapering Branches.

In the elevation the branch is shown by J K L M N and the half profile of small end by K R L.

An inspection of the engraving will show that the perimeter of the larger end of the branch must be divided into three parts, two of which form the joints or connections with the branches on either side of it while the third part must form one-third of the base or circumference of the large pipe with which it is to be united. In the elevation P M represents the plane of the base or upper end of the round pipe of which A B C is the profile or plan, and J O is assumed as the hight of the central point at which all the branches meet. From J of the elevation or G of the plan to either of the three points A, B or C any suitable curve may be chosen as the profile upon which to make a joint or miter between adjacent branches. As J O is equal to G A or G C, a quarter circle is assumed as the most suitable curve; therefore from O as a center describe the quarter circle P J of the elevation, corresponding with A G of the plan. In order to complete the elevation of the branch J K L M N, it will be necessary to obtain the elevation of the miter line G C.

Therefore divide P J into any convenient number of equal parts, as shown by the small figures, and from the points thus obtained carry lines to the right parallel with P M. From G, on G C, set off spaces equal to the distances from the points in P O to the line O J, as shown, and from the points thus obtained in G C erect perpendiculars cutting lines of similar number drawn from P J. A line traced through these points of intersection, as shown by J N, will give the miter line in elevation corresponding with G C of the plan. Divide C H of the plan into the same number

of equal parts as P J of the elevation, and from the points thus obtained erect perpendiculars cutting N M. Divide K R L, the profile of the smaller end of the branch, into the same number of equal parts as the larger end—that is, as many as are found in J N M—and from the points of division drop lines perpendicular to K L, cutting the same. Connect points in K L with those in J N M by solid and dotted lines in the manner shown in the drawing. Upon all of these lines it will be necessary to construct sections in order to obtain the true distances as if measured upon the surface of the branch. As each of the branch pipes consists of symmetrical halves when divided by the line G F of the plan half sections only need be constructed, all projections being measured from the dividing plane represented by G F in the plan and shown in elevation by J K L M N.

In Fig. 686 are shown the sections having for their bases the solid lines of the elevation, which are constructed in the following manner: Upon any horizontal line, as P Q, set off from P the lengths of the several solid lines of the elevation, as indicated by the small figures corresponding with those in J N M. At P, which corresponds with all the points in K L of the elevation, erect a perpendicular, P H, upon which set off the hights of the points in K R L, as 2′ 2, 3′ 3, etc., shown by P 2, P 3, etc. At each of the points near Q erect a perpendicular, which make equal in hight to the length of line drawn from the point of corresponding number in G C H of the plan to the line G H. Thus make 9′ 9, 10′ 10, etc., equal to 9″ *a*, 10″ *b*, etc., of the plan. From the points 9, 10, etc., draw solid lines to the points in H P, connecting points correspondingly connected by the solid lines of the elevation. The sections having for their bases the dotted lines of the elevation are shown in Fig. 687, and are constructed in exactly the same manner. Upon Y Z, set off from Y the lengths of the dotted lines of the elevation, numbering the points near Z to correspond with those in J N M of the elevation. The perpendiculars erected from these points are the same as those similarly located in Fig. 686, and the perpendicular X Y is a duplicate of H P of Fig. 686. From the points 9, 10, 12, etc., draw dotted lines to points in X Y, connecting points correspondingly connected by dotted lines of the elevation.

To describe the pattern shown in Fig. 688 proceed as follows: Draw any line, as J K, in length equal to J K of elevation, Fig. 685. With K of pattern as center, and K 2 of profile as radius, describe a small arc (2), which cut with one struck from J of pattern as center, and 8′ 2 of Fig. 687 as radius, thus establishing point 2 of pattern. With point 2 of pattern as center, and 9 2 of Fig. 686 as radius, describe another small arc (9), which intersect with one struck

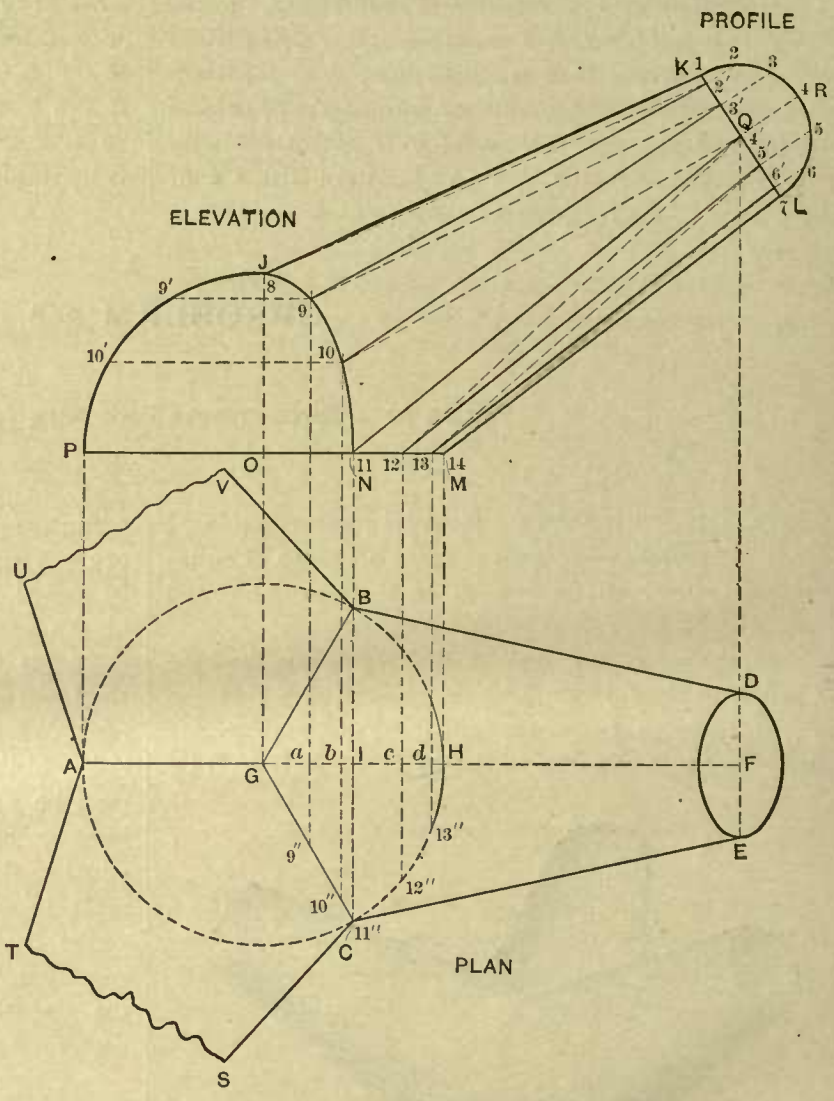


Fig. 685.—Plan and Elevation of Three-Pronged Fork.

from J of pattern as center, and J 9′ of elevation as radius, thus establishing the point 9 of pattern. Pro-

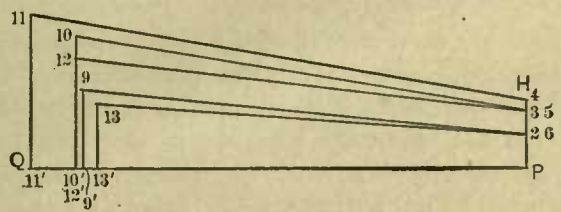


Fig. 686.—Diagram of Sections Upon Solid Lines in J K L M N of Fig. 685.

ceed in this manner until the remaining points are located, all as clearly indicated by the solid and dotted lines in Fig. 688. By drawing lines through the

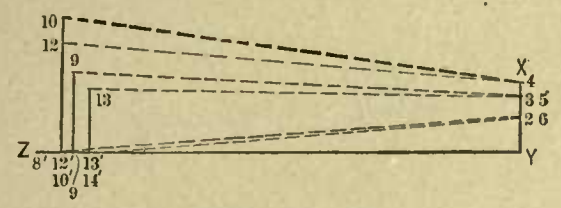


Fig. 687.—Diagram of Sections Upon Dotted Lines in J K L M N of Fig. 685.

points thus obtained the half pattern shown by K Q L M N J is the result. The other half, as shown by

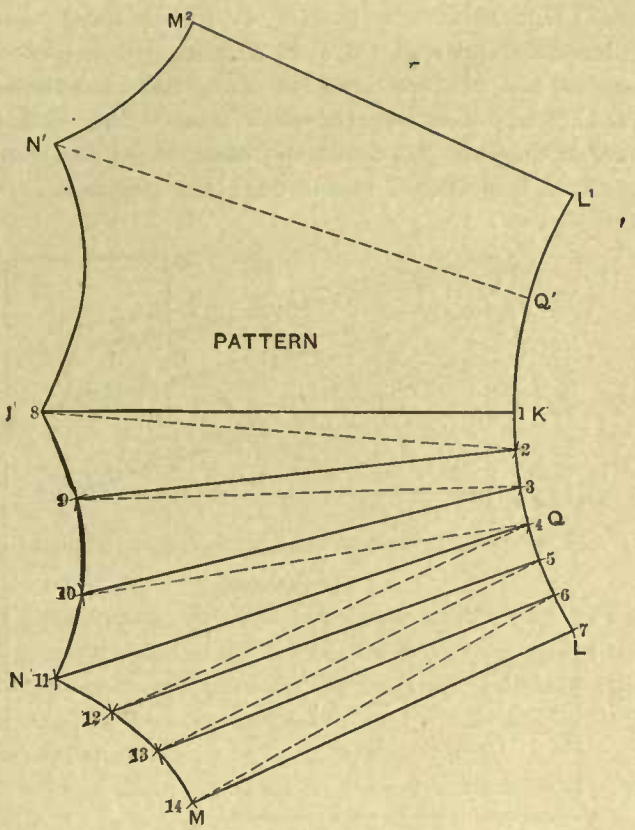


Fig. 688.—Pattern of Tapering Branch.

K Q′ L′ M′ N′ J, can be obtained in a similar manner, or by duplication.

PROBLEM 209.

The Pattern for an Offset to Join an Oblong Pipe With a Round One.

In Fig. 689, B C F G represents the side elevation of the offset, A B G H a portion of a round pipe joining it below, and C D E F a portion of the oblong pipe joining it above. In the plan immediately below, J K L M shows the plan of the round pipe and N O P Q R S that of the oblong pipe, while the distance L T shows the amount of the offset.

The piece forming the offset is similar in shape to that shown in Problem 189, the difference being that its bases B G and C F are neither horizontal nor parallel to each other and that sections on the lines of the bases are not given. Since the article required consists of symmetrical halves when divided on the line J T of the plan, the plane surface A B C D E F G H lying as it were back of the half shown by the elevation may, as in Problem 207, be regarded as a base from which to measure all hights, or projections, in obtaining the required profiles and sections necessary in developing the pattern. The first steps necessary will be to obtain true sections upon the lines C F and B G of the elevation. In Fig. 690, C D E F represents a duplicate of the part bearing the same letters in the elevation. Upon D E as a base line construct a duplicate of the half section of oblong pipe N O P T of Fig. 689, as shown by D N P E.

Divide the semicircle N P into any convenient number of equal parts, as shown by the small figures. With the blade of the T-square placed at right angles

to D E, drop lines cutting C F. With the T-square placed at right angles to C F, and brought against the points in C F, draw lines, extending them indefinitely, as shown. Measuring in each instance from C F, set off on the lines just drawn the same length as similar lines in D N O P E, and through the points thus ob-

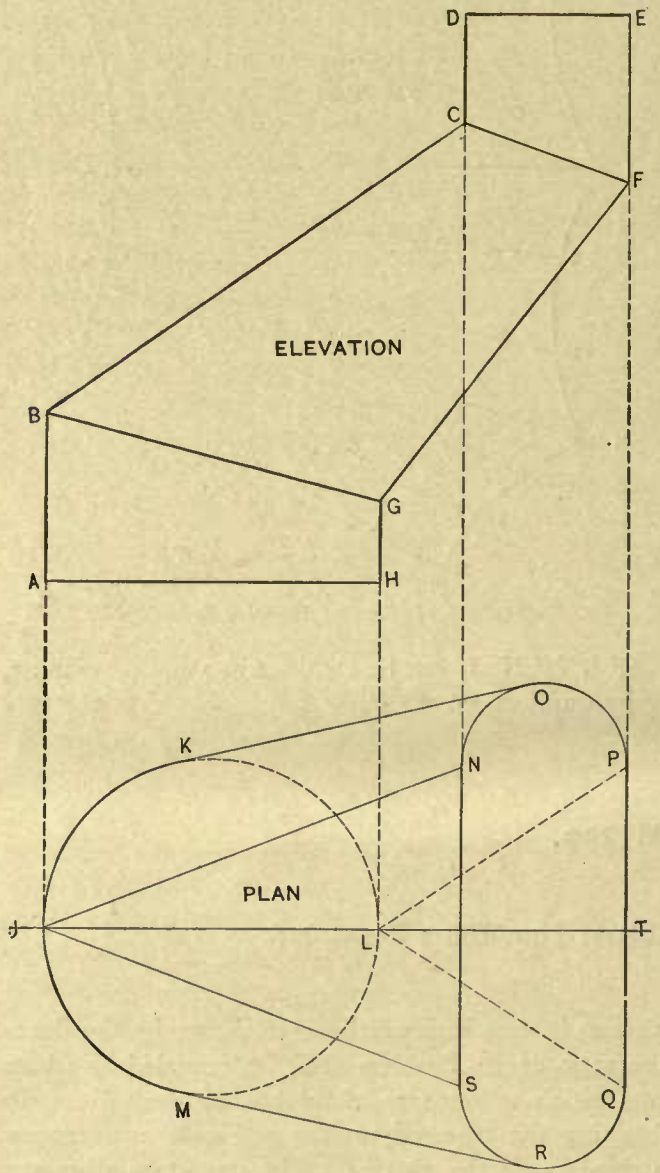


Fig. 689.—Plan and Elevation of Offset.

tained trace a line, as shown by *n* O *p*. Then C F *p* O *n* is the half shape of cut on line C F. In Fig. 691, A B G H is a duplicate of the elevation of the round pipe, below which is drawn a half profile of same, A M H. To obtain the shape of cut on line B G, divide the half profile A M H into the same number of parts as was N P, and, with the T-square placed parallel with A B, and brought successively against the points in A M H, carry lines cutting B G. With the T-square placed at right angles to B G, and brought against the

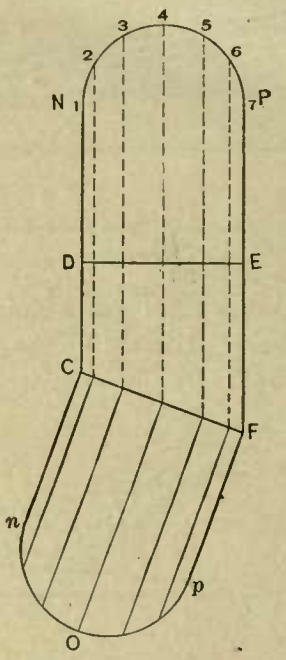


Fig. 690.—Development of Section on Line C F of Elevation.

points therein contained, erect perpendiculars, as shown. Measuring in each instance from B G, set off on the lines just drawn the same length as similar lines in A

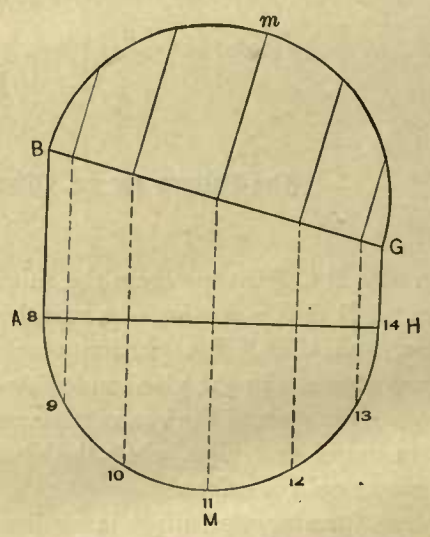


Fig. 691.—Development of Section on Line B G of Elevation.

M H, and through the points thus obtained trace a line, as shown by B *m* G. Then B *m* G is the half shape of cut on line B G.

In order to avoid a confusion of lines a duplicate

of B C F G of the elevation is presented in Fig. 692, upon C F and B G of which, as base lines, are drawn duplicates of the sections obtained in Figs. 690 and 691, all as shown. From points in *n* O *p* drop lines at right angles to C F, cutting the same, and from points in B *m* G drop lines at right angles to B G, cutting it. Connect points in these lines in consecutive order by solid lines, as shown, and subdivide the four sided figures thus obtained by dotted lines representing their shorter diagonals. The surface of the offset or transition piece is thus divided into a series of very tapering triangles, the lengths of whose bases or shortest sides

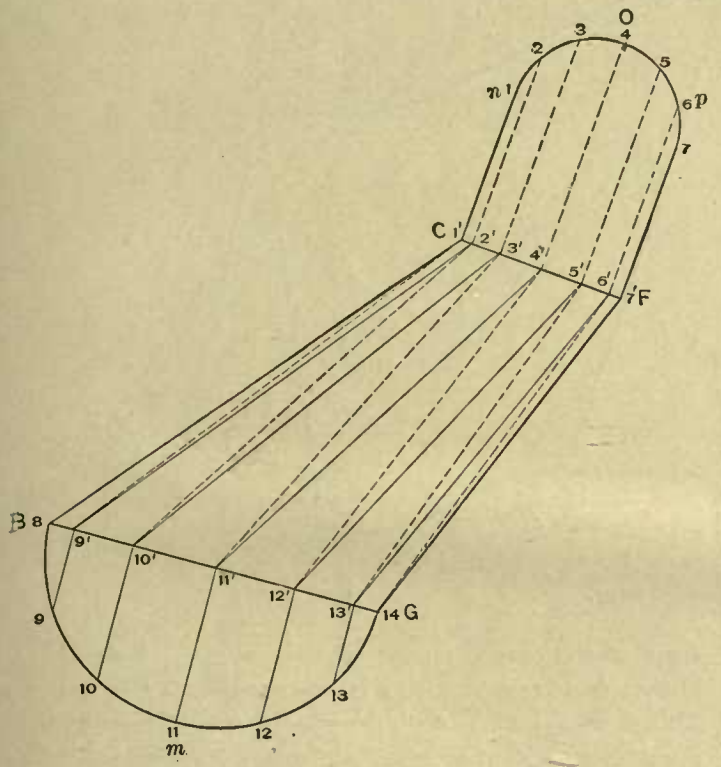


Fig. 692.—Middle Piece of Offset, Showing Method of Triangulation.

are given in the two sections C *n* O *p* F and B *m* G. In order to obtain the correct lengths of their longer sides two diagrams or series of sections must be constructed for that purpose, which are shown in Figs. 693 and 694.

To obtain the various sections on the solid lines of the elevation proceed as follows: Draw the right angle U V W, Fig. 693. From V, on V U, set off the length of lines in B *m* G, Fig. 692. From V, on V W, set off the length of solid lines in B C F G, and from the points thus obtained erect perpendiculars, in length equal to lines of similar number in C *n* O *p* F, Fig. 692. Thus make line W 1′ of Fig. 693 equal to line C *n* or C 1, and draw V 1′, which gives the distance from point B to point *n* in Fig. 692 as if measured on the finished article. Connect the perpendiculars drawn from V W with the points in V U, as shown, and corresponding with the figures in Fig. 692. Thus connect 1′ and 8, 2′ and 9, 3′ and 10, etc. Then

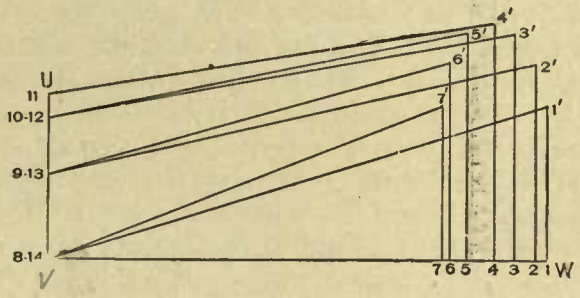


Fig. 693.—Diagram of Sections on Solid Lines of Fig. 692.

will the lengths of the oblique lines in Fig. 693 be the true lengths of the solid lines crossing the elevation. The diagram of sections shown in Fig. 694 is constructed in the same manner, using the dotted lines of the elevation as the basis of measurements.

Draw the right angle X Y Z, and from Y set off on Y Z the length of lines in C *n* O *p* F. From Y, on Y X, set off the length of dotted lines in B C F G, and from the points thus obtained erect perpendiculars, in length equal to lines of similar number in B *m* G, as indicated by the small figures. Connect the perpendiculars drawn from X Y with the points in Y Z, as shown, and corresponding with the figures in B C F G. Thus connect 1 and 9′, 2 and 10′, 3 and 11′, etc.

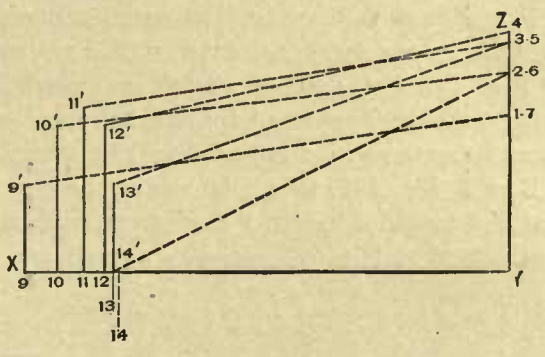


Fig. 694.—Diagram of Sections on Dotted Lines of Fig. 692.

An inspection of the plan and elevation, Fig. 689, will show that the curved surface of the offset or transition piece B C F G, which has been divided into triangles, is shown by J M L Q R S of the plan, and that this piece is connected with its mate or equivalent in

the opposite half of the article by a large plain triangular surface, S J N, on the upper side, and by another, Q L P, on its lower side, which must be added to the pattern of the curved portion after it has been developed. It will also be seen that V W 1′ of Fig. 693 is one-half of J N S. Therefore to develop the pattern, first draw any line, as *j x* in Fig. 695, in length equal to B C of Fig. 689, or V W of Fig. 693. With *j* as center, and 1′ V of Fig. 693 as radius, describe a small arc (near *s*), which intersect with another small arc struck from *x* as center, and with a radius equal to W 1′ of Fig. 693, thus duplicating the triangle V W 1′. From *s*, or point 1, as center, with a radius equal to 1 9′ of Fig. 694, describe a small arc (near 9), which intersect with another small arc struck from *j* or 8 of pattern as center, with a radius equal to 8 9 of the profile B *m* G, Fig. 692, thus establishing the position of point 9 of pattern. From 9 as a center, with a radius equal to 9 2′ of Fig. 693, describe a small arc, which intersect with another small arc struck from point 1 of pattern as center, and a radius equal to 1 2 of the profile C *n* O *p* F of Fig. 692, thus establishing the position of point 2 of pattern. Proceed in this manner, using the dotted oblique lines in Fig. 694, the lengths of the spaces in B *m* G in Fig. 692, the lengths of the solid oblique lines in Fig. 693 and the lengths of the spaces in C *n* O *p* F of Fig. 692 in the order named until the line 7 14 is reached. Lines traced through the points of intersection from *j* to *l* and from *s* to *t* will give the

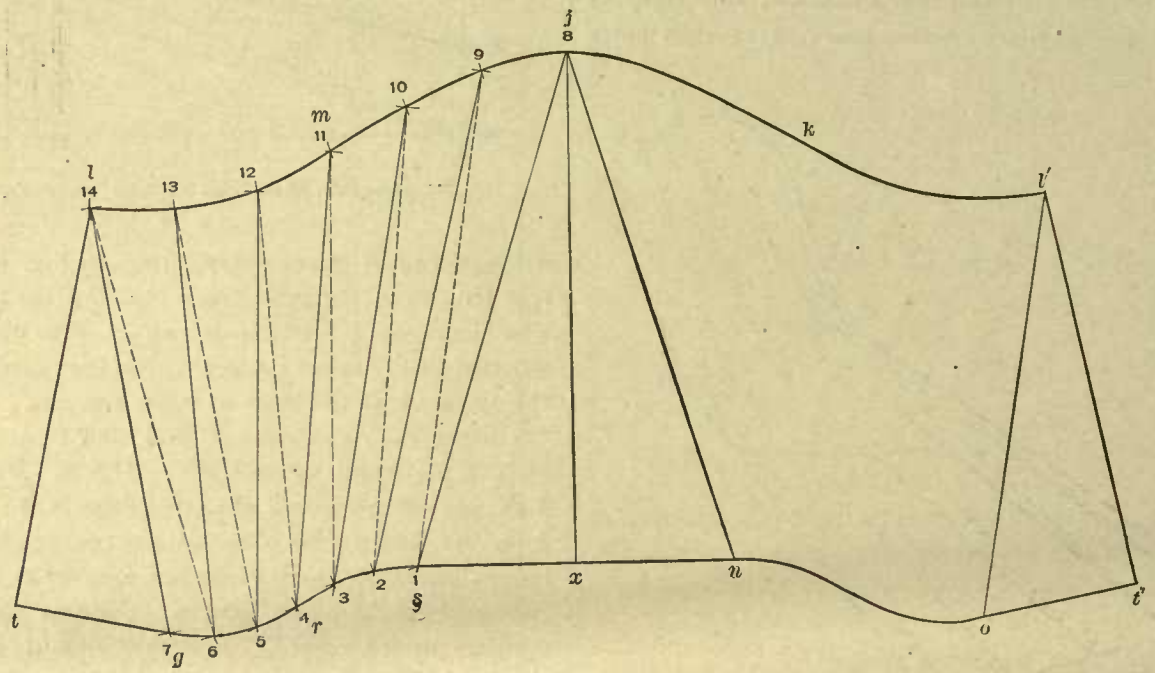


Fig. 695.—Pattern of Offset.

shape of the curved portion of the pattern. From 14 of pattern as center, with a radius equal to G F of Fig. 692, or V 7 of Fig. 693, describe a small arc, which intersect with another small arc struck from point 7 of pattern as center, and a radius equal to 7 7′ of Fig. 693, or T P of the plan. Draw 7 *t* and *t l*; then will *l j x s g t* be one-half the pattern required. The other half can be obtained by any means of duplication most convenient.

PROBLEM 210.

Pattern for an Offset to Join a Round Pipe with one of Elliptical Profile.

This problem differs from the preceding one only in the shape of the pipe having the elongated profile, which profile in the preceding problem consists of two semicircles joined by a straight part, whereas in this case its curve is continuous throughout; its pattern therefore will consist throughout of a series of triangles

having short bases instead of having a large flat triangular surface uniting its curved portion as in the previous case.

In Fig. 696, D C B A represents the elevation of the offset, C F E B that of a portion of the round pipe with which it is required to connect at its upper end

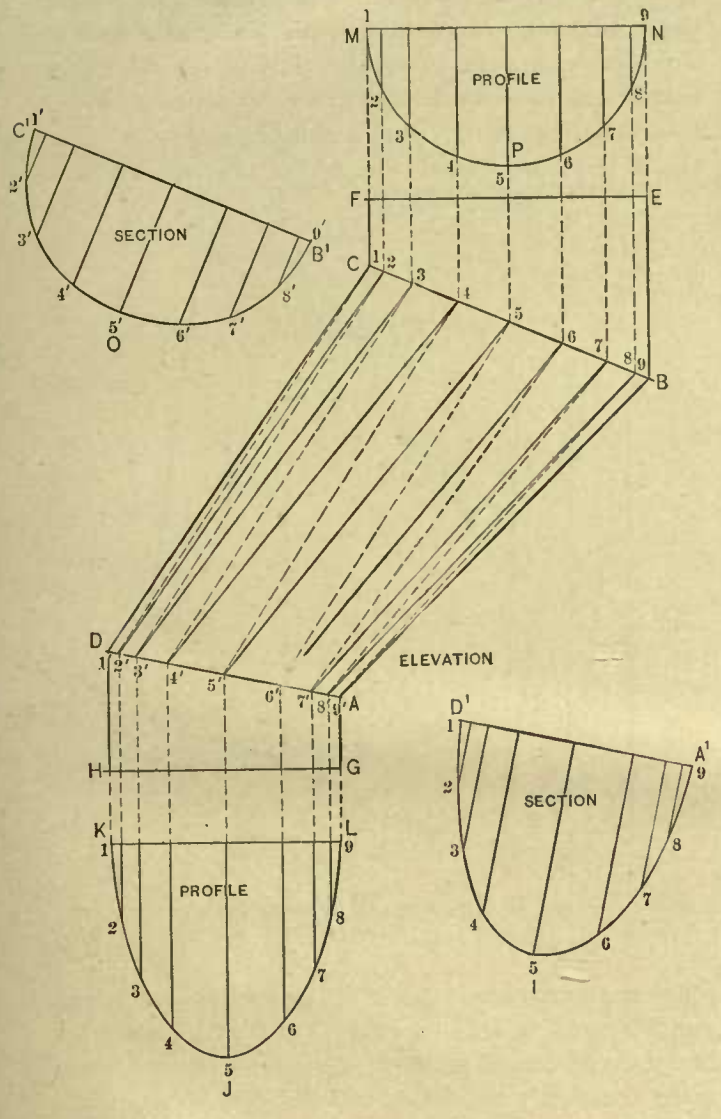


Fig. 696.—Elevation and Sections of Offset, Showing Method of Triangulation.

and H D A G that of the elliptical pipe joining it below. M P N is the half profile of the round pipe and K J L that of the elliptical pipe. The plan or top view is not shown, and is not necessary to the work of obtaining the pattern. Since the profiles given necessarily represent sections on lines at right angles to the respective pipes, as at F E and H G, it will first be necessary to derive from them sections on the joint or miter lines C B and D A, from which to obtain correct stretchouts of the two ends of the pattern of the offset piece.

As the pattern required consists of symmetrical halves, one-half only will be given, and one-half of the profiles only need be used. Therefore divide the half profile M P N into any convenient number of equal spaces, as shown by the small figures, and from the points thus obtained draw lines at right angles to F E, cutting M N and C B. To avoid confusion of lines a duplicate of C B is shown at the left by C' B'. From the points on C' B' draw lines at right angles to it indefinitely, and upon each of these lines, measuring from C' B', set off the lengths of lines of corresponding number in the profile M P N measured from M N. Thus make the distance of point 2′ from C' B' equal to the distance of point 2 from line M N, the length of line 3′ equal to that of line 3, measuring from the same base lines as before, etc. A line traced through the points of intersection, as shown by C' O B', will be the correct section on the line C B of the elevation. The method of obtaining the section on the line D A, shown at D' I A', is exactly the same as that just described in connection with the round pipe, all as clearly shown in the lower part of the engraving.

The next operation will consist of dividing the surface of the transition or offset piece into measurable triangles, making use of the spaces used in the profiles; therefore connect points in C B with those of similar number in D A by solid lines, as 1 with 1′, 2 with 2′, etc., and connect points in C B with those of the next higher number in D A by dotted lines, as 1 with 2′, 2 with 3′, 3 with 4′, etc. The surface of the transition piece is thus divided into a series of triangles the lengths of whose bases or short sides are found in the two sections C' O B' and D' I A'.

As the hights of corresponding points in the two sections, measuring from their center or base lines, differ very materially, it will be necessary to construct two diagrams of sections from which the lengths of the various solid and dotted lines can be obtained. In Fig. 697 is shown a diagram of sections through A B C D taken on the solid lines drawn across the elevation, in which the base line P Q represents the surface of a plane dividing the offset into symmetrical halves. At P erect a perpendicular, P R, upon which set off the hight of the points in the profile K J L or the section D' I A', measuring upon the straight lines joining them with the base line K L, as shown by the small figures. From P, upon P Q, set off the lengths

of the various solid lines drawn across the elevation, also shown by small figures, and at each of the points thus obtained erect a perpendicular, which make equal in hight to the distance of point of corresponding number in profile M P N from M N, measuring on the perpendicular line. Thus, make line 2 of Fig. 697 equal

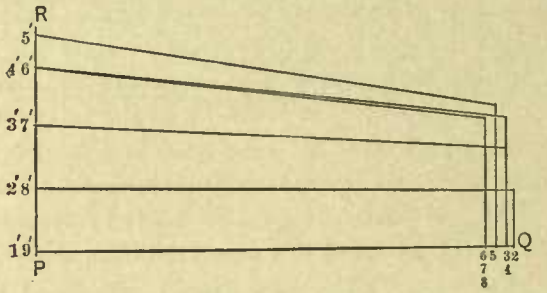


Fig. 697.—Diagram of Sections on Solid Lines of Elevation.

in hight to the distance from point 2 of profile to the line M N, line 3 equal to the length of line 3 of profile M P N. Now connect points of corresponding number at the two ends of the diagram by straight lines, as shown, then will these oblique lines be the correct distances between points of corresponding numbers connected by the solid lines drawn in the elevation.

The diagram in Fig. 698 is constructed in an exactly similar manner. The distances S 1, S 2, S 3, etc., on the base line are in this case made equal to the lengths of the dotted lines of the elevation, and the

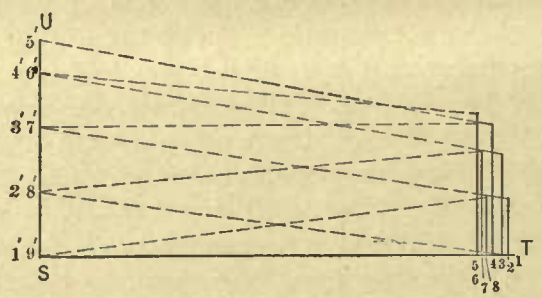


Fig. 698.—Diagram of Sections on Dotted Lines of Elevation.

perpendiculars erected at points 2, 3, etc., are the same as those used in the previous diagram. The perpendicular S U is also an exact duplicate of P R in Fig. 697. In drawing the oblique dotted lines, point 1 at the right end of the diagram is connected with that of the next higher number (2′) on the line S U, 2 at the right with 3′ on the line S U, etc., all as shown. The oblique dotted lines will then be the correct distances between points of corresponding numbers connected by the dotted lines in the elevation.

To develop the pattern, first draw any straight line, as D C in Fig. 699, which make equal in length to D C of Fig. 696. From D as center, with a radius equal to 1 2 of the section D′ I A′, strike a small arc, which intersect with another small arc struck from C as center, with a radius equal to 2′ 1 of Fig. 698, thus establishing the location of point 2′ of pattern. From 2′ of pattern as center, with a radius equal to 2′ 2 of Fig. 697, strike a small arc, which intersect with another small arc struck from C of pattern as center, and a radius equal to 1 2 of section C′ O B′, thus establishing the position of point 2 of pattern. So continue, using alternately the dotted and the solid oblique lines in Figs. 698 and 697 to measure the distances across the pattern, the spaces from the section D′ I A′ to form the stretchout of the lower end (D A) of pattern, and the spaces from the section C′ O B′ to form the stretchout of the upper end (C B) of the pattern. Lines traced through the points of intersection, as from C to B and from D to A, will complete one-half the required pattern.

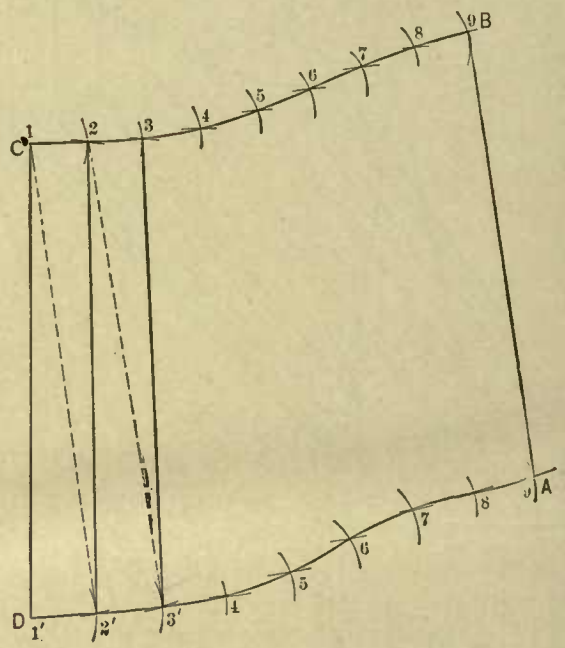


Fig. 699.—Half Pattern of Offset Piece.

PROBLEM 211.

The Patterns for a Funnel Coal Hod.

In Fig. 700 are shown the drawings for a funnel coal hod of a style in general use. In preparing such a set of drawings it is necessary that care should be taken to have a correspondence of all the principal parts in the two views, as shown by the dotted lines, leaving the final drawing of the curves to be more accurately performed as circumstances may require in subsequent parts of the work. The design is capable of any degree of modification so far as the proportions of its parts are concerned without in the least affecting the method of obtaining its patterns. Thus, hights, lengths, diameters or curves may be changed at the discretion of the designer. The coal hod is here constructed in two pieces, the front being in one piece joined together on the line B C of the elevation or B^2 C^2 of the plan, and joined to the back piece on the line H D. As will be seen by an inspection of the elevation, the front piece consists of a flat triangular piece, H J D, joined to two irregular flaring pieces, A J H G and B J D C. On account of the taper or slant of the flat portion of the front piece, as shown by J^2 D^2 of the plan, the line D^2 H^1 has been drawn somewhat obliquely from X, the center of the bottom, instead of at right angles to A^2 E^2.

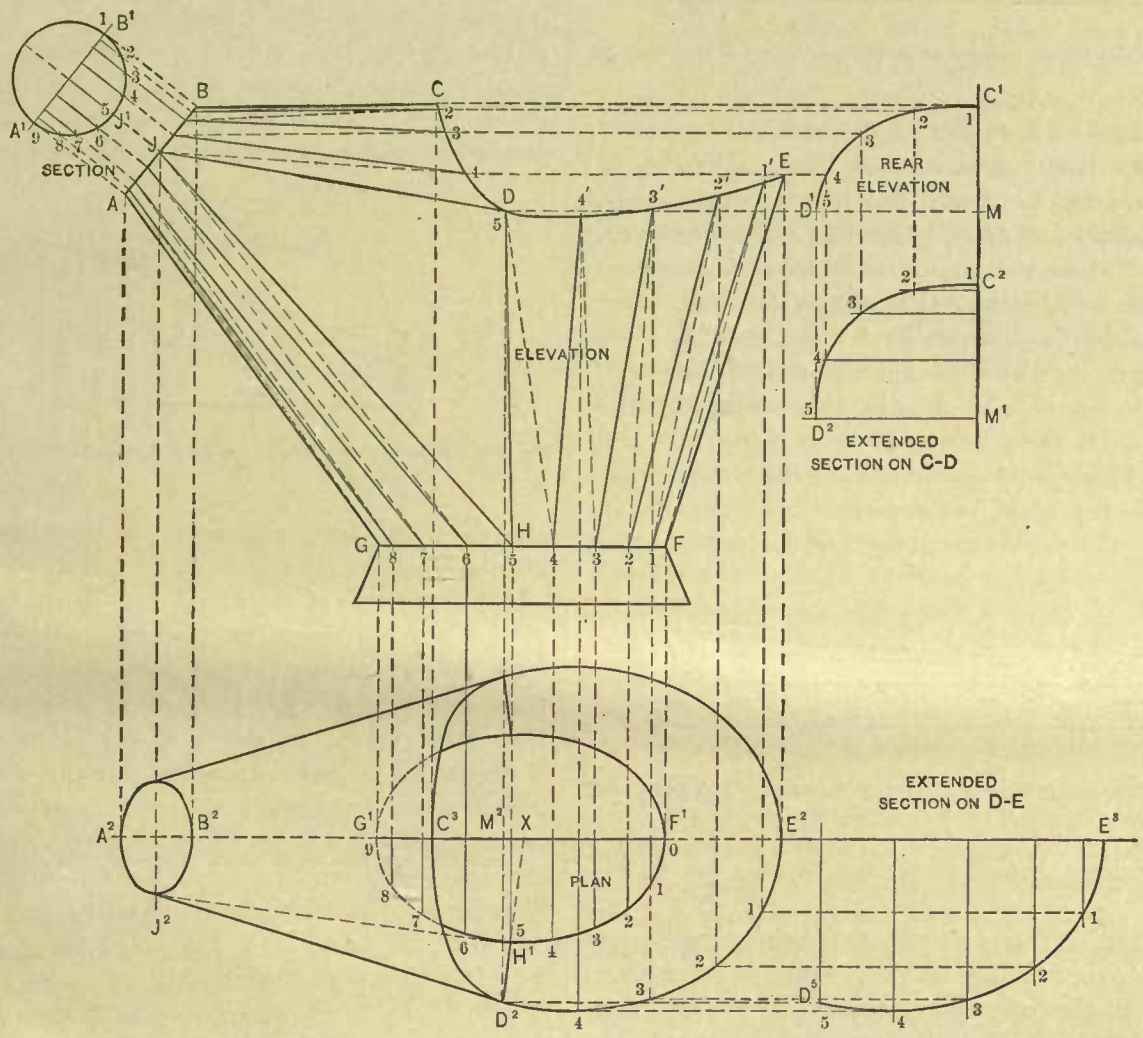


Fig. 700.—Plan, Elevation and Sections of a Funnel Coal Hod, Showing Method of Triangulation.

The section at A B is assumed to be a perfect circle and should be drawn exactly opposite, as

shown, its vertical center line A' B' being placed parallel to A B. Divide each quarter of this, as A' J' and J' B', into any number of equal spaces, as shown by the small figures, and through the points thus ob-

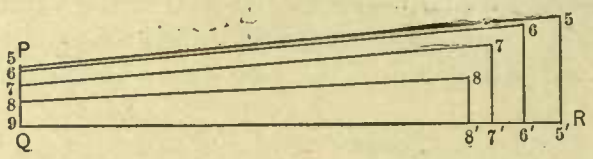


Fig. 701.—Diagram of Sections on Solid Lines in A J H G of Fig. 700.

tained draw lines cutting A' B' and A B. From J, the middle point on A B, draw lines to D and to H. Also divide H' G' of the plan into the same number of equal spaces as A' J', numbering the points to correspond. From the points thus obtained erect lines perpendicularly, cutting G H of the elevation. Connect points of like number on A J and G H, as 5 with 5, 6 with 6, etc., by solid lines, as shown; also, connect each point on A J with that of next higher number on G H by a dotted line, as 5 with 6, 6 with 7, etc. These solid and dotted lines just drawn are the lines upon which measurements are to be taken in obtaining the pattern, and upon which sections must

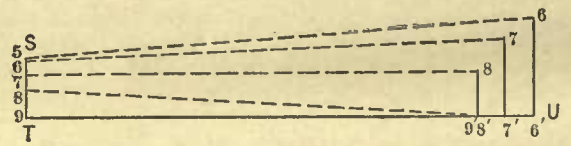


Fig. 702.—Diagram of Sections on Dotted Lines in A J H G of Fig. 700.

be constructed before their true lengths can be obtained.

In Fig. 701 are shown the sections having the solid lines in A J H G as their bases, which are constructed in the following manner: Draw any right angle, as P Q R. Upon P Q set off the hights of the several points in the section A' J' from the line A' B', as measured upon the straight lines joining them with A' B'; thus make Q 5 and Q 6 equal to the distance of points 5 and 6 from the line A' B'. From Q on Q R, measuring from Q, set off the lengths of the several solid lines in A J H P, as indicated by the small figures, and from the points thus obtained erect perpendiculars equal in hight to the length of lines drawn from points of corresponding number in G' H' of the plan to the line G' X; thus make the perpendiculars at points 5', 6', etc., equal to the length of the lines drawn from points 5 and 6 in G' H' to G' X. Connect the points thus obtained with points of corresponding number in P Q. The oblique lines thus obtained will be the true distances represented by lines of corresponding number in the elevation. The diagram in Fig. 702 shows the sections upon the dotted lines in A J H G and is constructed in the same manner. Upon T U, measuring from T, are set off the lengths of the several dotted lines. S T is the same as P Q of Fig. 701, and the perpendiculars at U are equal to those of corresponding number in Fig. 701. Points in S T are then connected with the perpendiculars of next higher number by dotted lines, which

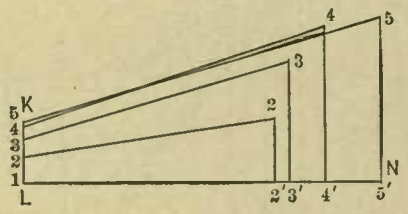


Fig. 703.—Diagram of Sections on Solid Lines in J B C D of Fig. 700.

give the true lengths represented by the dotted lines of the elevation.

That portion of the front piece shown by J B C D of the elevation must be triangulated in exactly the same manner as the portion just described, and sections constructed upon the several solid and dotted lines there drawn, as shown in Figs. 703 and 704. However, as no outline is given in either the plan or the elevation from which a correct stretchout of C D can be obtained, a section must be constructed for that purpose, which can be done in the following manner: First draw C' M' as the vertical center line of a rear

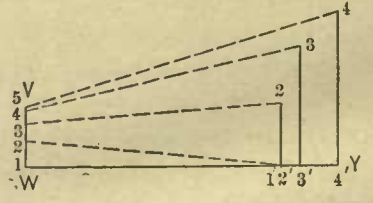


Fig. 704.—Diagram of Sections on Dotted Lines in J B C D of Fig. 700.

elevation. From points C and D project lines horizontally to the right, cutting C' M' at C' and M. Upon D M, measuring from M, set off half the width of the front piece at D' of the plan; that is, make M D'

equal to $M^2 D^2$. Any desirable curve may then be drawn from D^1 to C^1, representing the rear elevation of curve represented by D C of the side elevation. As the distance from C to D is much greater than C^1 M, an extended profile, as measured upon C D, must now be developed from which to obtain a correct stretchout of that portion of the pattern.

Therefore divide the curve C^1 D^1 into the same number of parts as the quarter circle B^1 J^1, and from the points thus obtained carry lines horizontally to the left, cutting C D. Upon C^1 M extended, as C^2 M^1, set off spaces equal to those in C D, as shown, and through

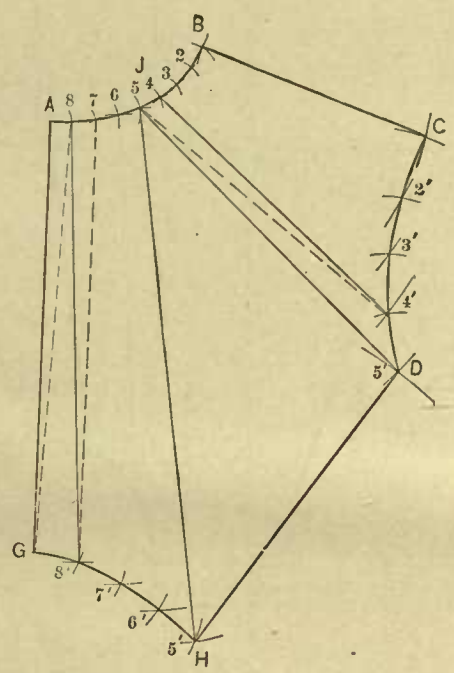


Fig. 705.—Half Pattern of Front Piece of Funnel Coal Hod.

the points thus obtained draw lines to the left indefinitely. From the points in C^1 D^1 drop lines vertically, cutting those just drawn, all as shown. A line traced through the points of intersection, as shown from D^2 to C^2, will give the desired stretchout. In dividing the curve C^1 D^1 into spaces it is advisable to make those nearest to D^1 less than those near the top of the curve in order to compensate for the increase in the spaces in C^2 M^1 as they approach the bottom; thus obtaining a set of nearly equal spaces upon the final profile D^2 C^2, all of which will appear clear by an inspection of the drawing.

As above stated, the diagrams of sections in Figs. 703 and 704 are constructed in the same manner as those of Figs. 701 and 702. The hights in K L and V W are taken from J^1 B^1 of Fig. 700 and are the same as those in P Q and S T of Figs. 701 and 702. The distances upon L N and W Y are those of the solid and dotted lines in J B C D of Fig. 700, and the hights of the perpendiculars near N and Y are equal to the lengths of the lines drawn from points of corresponding number in the profile D^2 C^2 of Fig. 700 to the lines C^2 M^1.

To develop the pattern of the front piece, first draw any line, as A G in Fig. 705, equal in length to A G of Fig. 700. From G as a center, with a radius equal to the dotted lines 9 8 of Fig. 702, describe a short arc (near 8), which intersect with another arc drawn from A as center, with a radius equal to 9 8 of the section A^1 J^1 B^1 of Fig. 700, thus establishing the position of point 8 in the upper line of the pattern. From 8 of the pattern as center, with a radius equal to 8 8 of Fig. 701, describe a short arc (near 8′), which intersect with another arc drawn from G of the pattern as center, with a radius equal to 9 8 of the plan, Fig. 700, thus establishing the point 8′ in the lower line of the pattern. Continue in this manner, using the lengths of the oblique dotted lines in Fig. 702 in connection with the spaces in the section A^1 J^1 B^1 of Fig. 700 as radii to determine the points in the upper line of the pattern, or the side forming the mouth, and the lengths of the oblique solid lines of Fig. 701 in connection with the spaces in the plan of the bottom (G^1 H^1) as radii with which to determine the points in the lower line of the pattern or the side to fit against the bottom.

Having reached the points 5 and 5′, next add to the pattern the flat triangular surface shown by J H D of the elevation. From H (5′) of the pattern as center, with a radius equal to 5 5 of Fig. 706, the side of the last triangle in the pattern of the back piece, describe a short arc (near D), and intersect the same with another arc struck from J (5) of the pattern as center, with a radius equal to the oblique line 5 5 of Fig. 703, and draw H D and D J. Using D J of the pattern as one side of the next triangle, take as radii the distances 5 4 of Fig. 704 and 5 4 of the section D^2 C^2 of Fig. 700 to locate the position of point 4′ of the pattern, as shown in Fig. 705. With 4 4 of Fig. 703, and 5 4 of the section B^1 J^1 of Fig. 700 as radii locate the point 4 of the pattern, as shown, and so continue until C D is reached. Lines traced through the points of intersection from B to A, C to D and H to G will complete the pattern of one-half the front piece.

The method of triangulating the piece forming the back of the coal hod and the development of the pattern of the same are so clearly shown in Figs. 706, 707 and 708, in addition to the plan and elevation, Fig. 700, as to need only a brief description. Divide H' F' and D² E² of the plan, Fig. 700, into the same

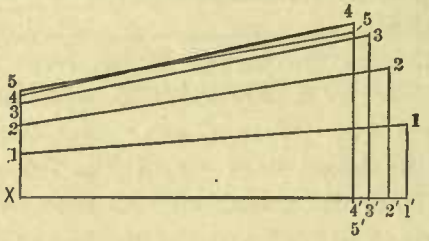


Fig. 706.—Diagram of Sections on Solid Lines in D E F H of Fig. 700.

number of equal parts, and from the points thus obtained erect lines vertically cutting the corresponding lines H F and D E of the elevation, as shown by the dotted lines. Connect points of like number in that view by solid lines and points in D E with those of next lower number in H F by dotted lines. Since D E, being inclined, is longer than M² E², its equivalent in the plan, it will be necessary to develop an extended section upon the line D E of the elevation, as shown by D⁵ E³ of the plan, which may be done in the same manner as the section on the line C D above explained. Upon M² E² extended, as E² E³, set off the

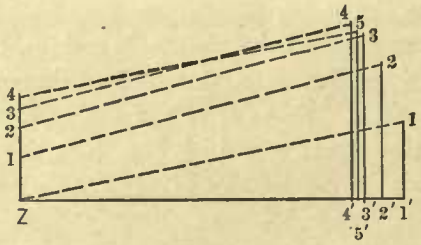


Fig. 707.—Diagram of Sections on Dotted Lines in D E F H of Fig. 700.

spaces in D E, and through the points thus obtained draw lines at right angles, as shown, which intersect with lines drawn parallel with M² E² from points of corresponding number in D² E², thus establishing the curve D⁵ E³, from which a correct stretchout of the top of the back piece may be obtained.

In Figs. 706 and 707, the hights of the various points upon the perpendiculars from X and Z are equal to the lengths of the straight lines drawn from points of corresponding number in H' F' of the plan, Fig. 700, to the line M² F'. The distances set off to the right upon the horizontal lines from X and Z are equal to the lengths of the several solid and dotted lines in D E F H of the elevation, and the hights of the perpendiculars at the right ends of the bases are equal to the straight lines drawn from points in the section D⁵ E³ to the line E² E³. The several oblique solid and dotted lines are, therefore, the true distances represented by the solid and dotted lines of corresponding number in the elevation.

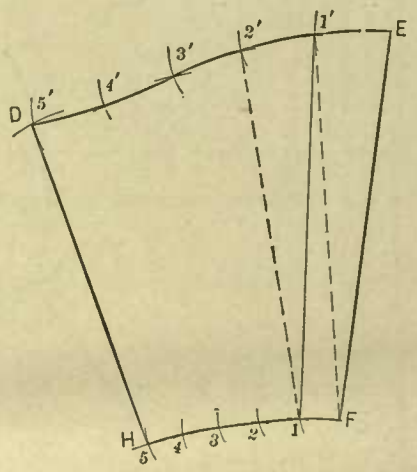


Fig. 708.—Half Pattern of Back Piece of Funnel Coal Hod.

In Fig. 708, E F is equal to E F of Fig. 700 and is made the base of the first triangle, from which base the several triangles constituting the complete pattern may be developed in numerical order and in the usual manner from the dimensions obtained in Figs. 706 and 707 and in the plan and section in Fig. 700, all as clearly indicated.

The pattern for the piece forming the foot of the coal hod is a simple frustum of an elliptical cone, the method of obtaining which is fully explained in Problem 171. In Fig. 546 of that problem the lines E F and G H are drawn much further apart than the proportions of the foot in the present case would justify, but the operation of obtaining its pattern is exactly the same.

PROBLEM 212.

Patterns for a Three-Piece Elbow to Join a Round Pipe with an Elliptical Pipe.

In Fig. 709, let A B C D represent the profile of the round pipe and E F G H I J K L the elevation of the elbow. In the plan the profile of round pipe is represented by A' B' C' D', the elbow by P' M' G' M² P², and the shape of elliptical end of elbow by J' M' G' M². The section J G H I of elevation is without flare, and sections K F G J and E F K L are flared, as shown in plan. Through the plan draw E' G' and M' M², and carry M' M² through the center of elevation, as shown by M N O P. Perpendiculars dropped from the points K O F of elevation, cutting P' M', E' G' and P² M², as shown by K' O' F' O², will give the shape of miter line K F in plan.

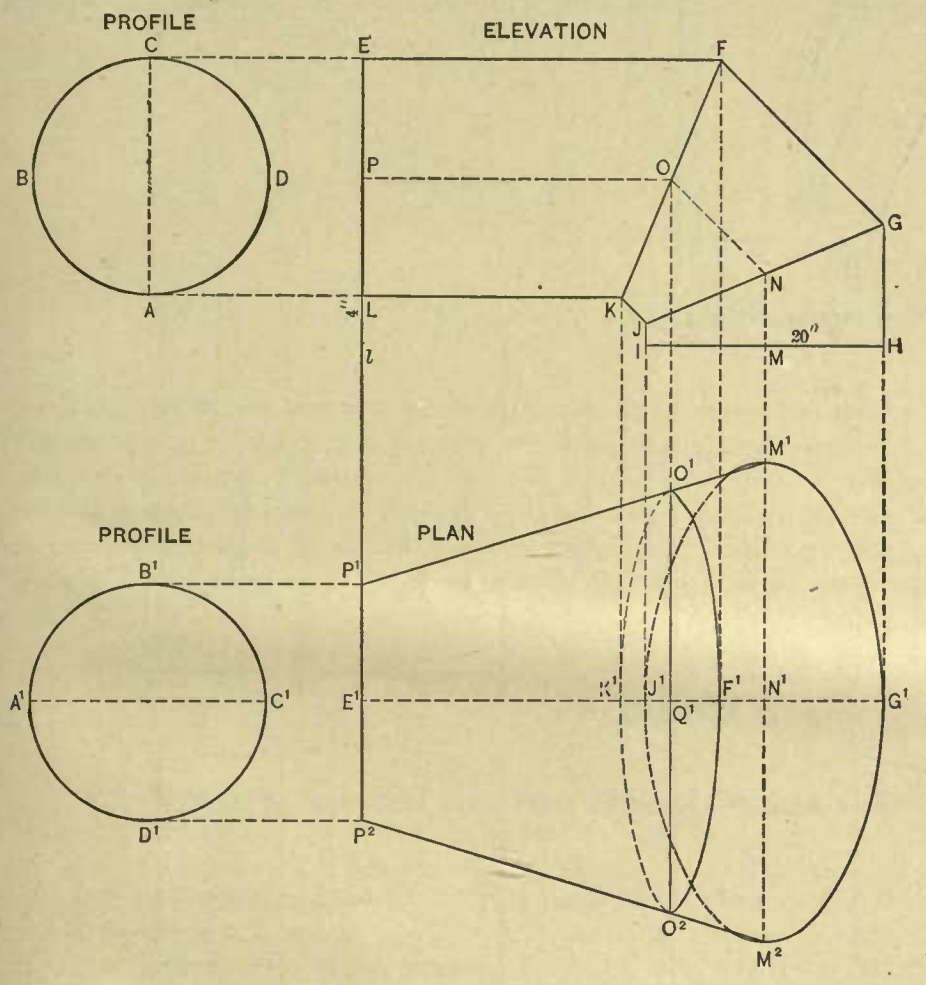


Fig. 709.—Plan and Elevation of Three-Piece Elbow, Round at One End and Elliptical at the Other.

As J G H I of elevation is without flare the pattern for this part is procured in the ordinary manner as for a pieced elbow. Since J' M' G' M² is the profile of an elliptical cylinder, the section upon the oblique line J G of the elevation, cutting the same, must necessarily be an ellipse whose major axis is equal to M' M² and whose minor axis is equal to J G. In like manner, the section at K F of the elevation may be assumed as an ellipse whose minor axis is K F and whose major axis is equal to O' O².

In Fig. 710, a duplicate of K F G J of elevation is shown by T R U W. Bisect T R in *d* and erect the perpendicular *d* S, and make *d* S equal to Q' O' of plan. Through the points T, S and R trace the half ellipse, as shown. In a similar manner bisect W U in *l*, and erect the perpendicular *l* V, in length equal to N' M' of plan. Through the points thus obtained trace the half ellipse W V U. Divide T S R into any convenient number of equal parts, and from the points thus obtained drop perpendiculars cutting T R, as shown. Also divide W V U into the same number of equal parts as was T S R, and from the points thus obtained drop perpendiculars cutting W U. Connect points in T R with those opposite in W U, as shown by the solid lines. Thus connect *a* with *h*, *b* with *j*, *c* with *k*, etc. Also connect the points in T R with those in W O, as indicated by the dotted lines. Thus connect 1 with *h*, *a* with *j*, *b* with *k*, etc.

The next step will be to construct a series of sections upon the several solid and dotted lines just drawn for the purpose of obtaining the true distances which they represent. The sections represented by solid lines

are shown in Fig. 711. To construct these sections proceed as follows: For section *a*, draw the line *a h*,

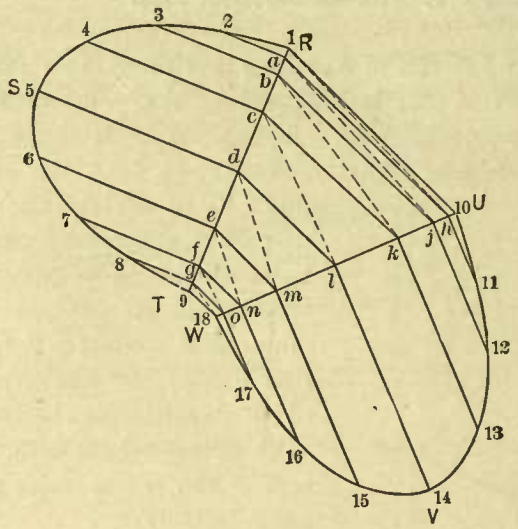


Fig. 710.—Elevation of Middle Section of Elbow, Showing Method of Triangulation.

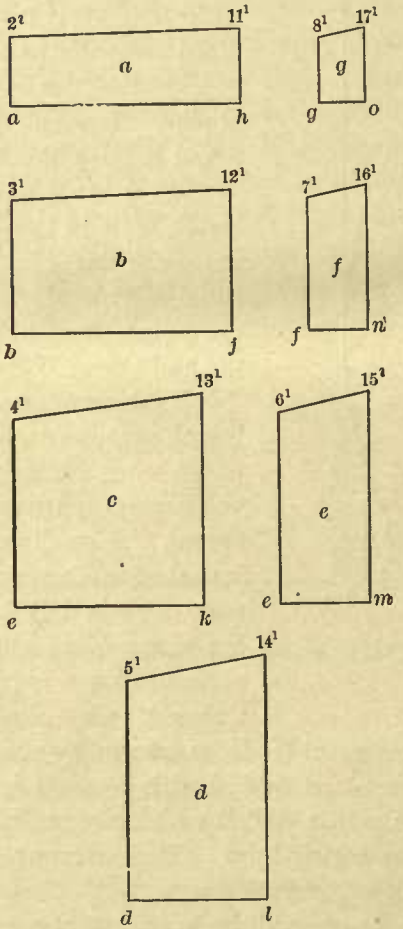


Fig. 711.—Sections on Solid Lines of Fig. 710.

in length equal to *a h* of Fig. 710. From *a* erect a perpendicular, in length equal to *a* 2 in T S R, as shown by *a* 2^1, and from *h* erect a perpendicular, in length equal to *h* 11 in W V U, as shown by *h* 11^1, and connect 2^1 11^1, as shown. For section *b*, draw *b j*, in length equal to *b j* of Fig. 710. From *b* erect the perpendicular *b* 3^1, in length equal to *b* 3 in T R S, and from *j* erect a perpendicular, in length equal to *j* 12 in W V U, and connect 3^1 12^1, etc. For the sections representing the dotted lines, as shown in Fig. 712, proceed in a similar manner. For section *h*, draw 1 *h*, in length equal to 1 *h* of Fig. 710. From *h* erect a perpendicular, in length

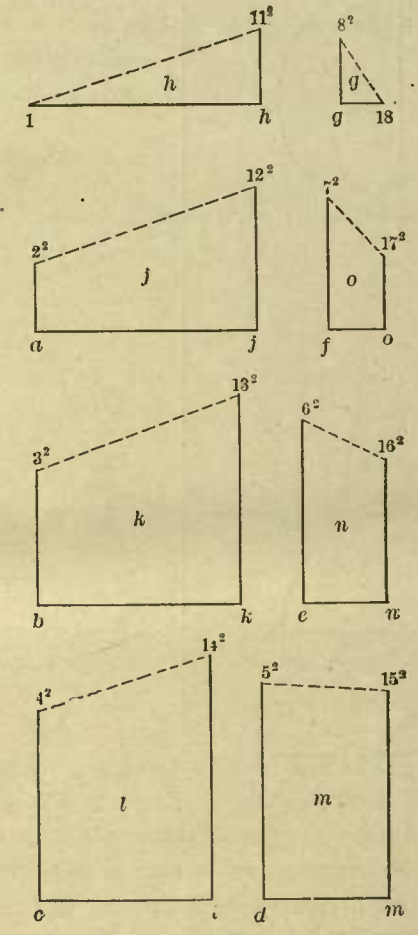


Fig. 712.—Sections on Dotted Lines of Fig. 710.

equal to *h* 11 in W V U, and connect 1 with 11^2. For section *j*, draw *a j*, in length equal to *a j* of Fig. 710. From *a* erect the perpendicular *a* 2^2, in length equal to *a* 2 in T S R, and from *j* erect a perpendicular, equal in length to *j* 12 in W V U, and connect 2^2 12^2, etc.

To describe the pattern for part of article represented in Fig. 710 by T R U W, as shown in Fig. 713, proceed as follows: Draw any line, as R V of pattern, in length equal to R U of Fig. 710. With R of pat-

tern as center, and 1 11^2 of the diagram of sections, Fig. 712, as radius, describe a small arc, which intersect with one struck from point V of pattern as center, and U 11 of Fig. 710 as radius, thus establishing the point 11 of pattern. With point 11 of pattern as center, and 2^1 11^1 of diagram of sections, Fig. 711, as radius, describe a small arc, which intersect with one struck from R of pattern as center, and R 2 of Fig. 710 as radius, thus establishing point 2 of pattern. Proceed in this manner, using the dotted lines in Fig. 712 for the distances in pattern represented by dotted lines; the spaces in W V U for the stretchout of V W^1 of pattern; the distances between points represented by numbers in Fig. 711 for the length of solid lines in pattern, and the spaces in R S T for the stretchout of R T^1 of pattern. Lines drawn through the points thus obtained, as indicated by R T^1 W^1 V, will be one-half of the required pattern. The other half, as shown by R T W V, can be obtained by a repetition of the same process or by duplication.

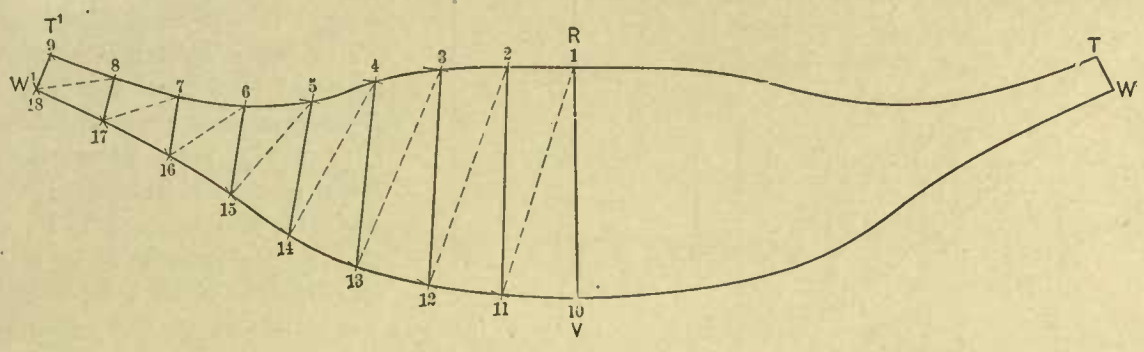


Fig. 713.—Pattern of Middle Section of Elbow.

The pattern for E F K L of elevation can be obtained in a similar manner, A B C of profile being one-half the shape on E L, and R S T of Fig. 710 being the half section on F K.

PROBLEM 213.

Patterns for a Right Angle Piece Elbow to Connect a Round with a Rectangular Pipe.

In Fig. 714 is shown the design of a right angle elbow of which one end is rectangular, as shown by N O P Q, and the other round, as shown by A B C D. Such an elbow may be constructed in any number of pieces, the elevation for which may be drawn in the manner described in the case of an ordinary piece elbow.

In the present instance the elbow consists of seven pieces. In adjusting the transition from the rectangle to the circle, it is evident that the flat sides of each of the five intermediate pieces must become shorter in each piece as the round end of the elbow is approached; and that the quarter circles forming the corners of each of the intermediate pieces must be of shorter radius as the corners of the rectangular end are approached. This may be accomplished upon the elevation in the following manner: Through the center of the elevation draw the lines *c* to *m*, and divide L *l'* into the number of parts there are pieces in the elbow subjected to the change in shape, in the present instance five. From *k'* set off each way four spaces, as shown by *k k'* and *k' k''*. Set off from *j''* three spaces, as shown by *j j'* and *j' j''*. Continue this operation and connect the points L *k j h g f* and *g'' h'' j'' k''* L', thus showing in side elevation the change from the rectangle N O P Q to the circle A B C D.

To show a similar shape on the outer curve of elbow, draw any line, as E M, in Fig. 715. From E on E M set off the spaces E F, F G, etc., to L M of Fig. 714. As it is only necessary to show the half

shapes, from M and L erect perpendiculars, in length equal to N *n* of profile, and connect same, as shown by M^2 L^2. Connect L^2 F, and from the points in E M

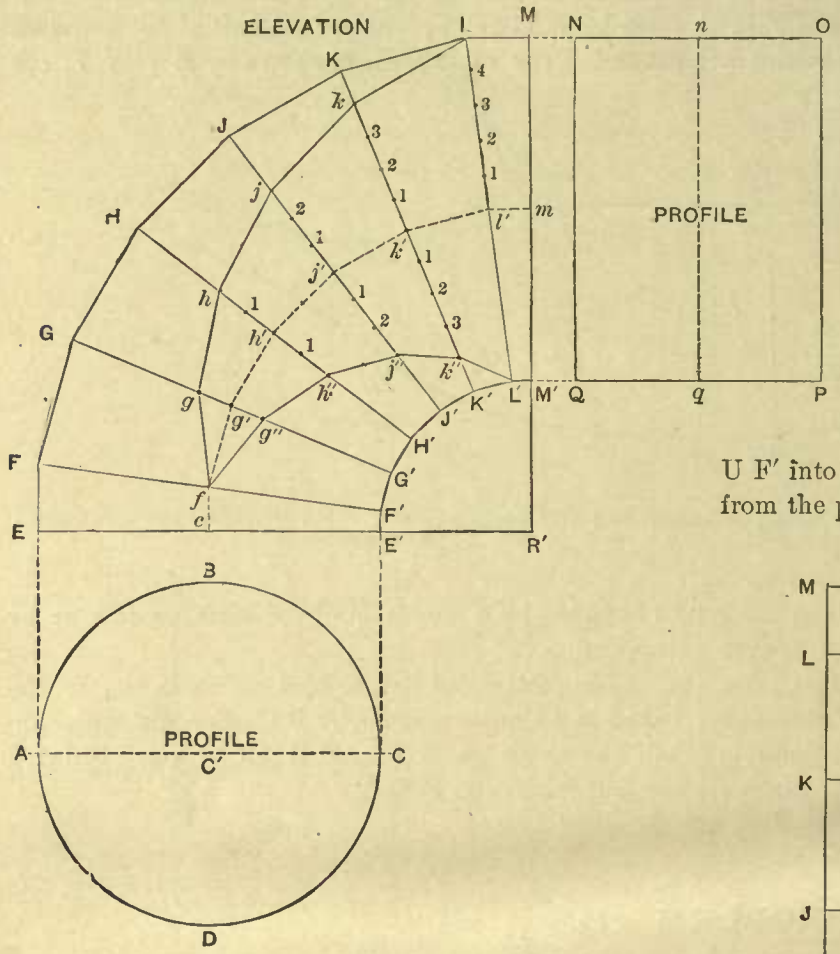


Fig. 714.—Elevation and Profiles of an Elbow to Connect a Round With a Rectangular Pipe.

erect perpendiculars cutting F L^2. The shapes on inner curve of elbow, as shown in Fig. 716, are obtained in the same manner as described for Fig. 715.

For the hights of section on *c m* of the elevation, on any line, as E M, in Fig. 717, starting from E, set off the distances *c f*, *f g'*, *g' h'*, etc., and from the points thus obtained erect perpendiculars, as shown. From E and F set off the distance C' B of profile of circular end and draw E^2 F^2. From M and L set off the distance N *n* of profile of rectangular end and draw M^2 L^2. Connect L^2 with F^2, thus completing the section.

The method for obtaining the patterns for sections E F F' E' and L M M' L' is the same as for an ordinary pieced elbow. The method for obtaining the pattern for one of the remaining sections will be shown, which will indicate the method to be followed in the other sections.

In Fig. 718, F G G' F' is a duplicate of the section having similar letters in elevation. The shape F U F' is the half of an ellipse, because F' F of Fig. 714 is an oblique section of a cylinder of which A B C D is the plan, and can be described in any convenient manner.

From G erect the perpendicular G S, equal to G G^2 of Fig. 715, and from G' erect another perpendicular, equal to G G^6 of Fig. 716. From points *g* and *g'* erect perpendiculars equal to G^3 G of Fig. 717, and connect T T', as shown. Connect S T and T' S' by a quarter of an ellipse. Divide S T, T' S', F U and U F' into any convenient number of equal parts, and from the points thus obtained drop perpendiculars cutting G G' and F F'. Connect these points, as shown by the solid and dotted lines in G G' F' F.

The next operation will consist in constructing sections upon these solid and dotted lines for the pur-

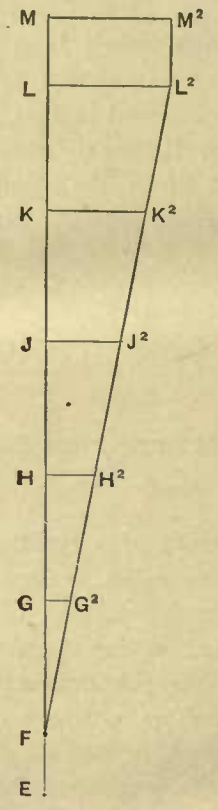


Fig. 715.—Shape of Flat Part of Outer Curve of Elbow.

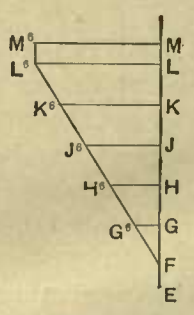


Fig. 716.—Shape of Flat Part of Inner Curve of Elbow.

pose of ascertaining the correct distances which they represent. These sections are shown in Figs. 719 and 720. To construct the sections represented by solid

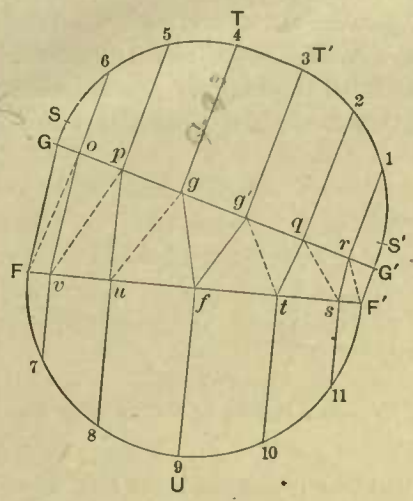


Fig. 718.—Elevation of One of the Pieces, Showing Method of Triangulation.

lines in Fig. 718, proceed as follows: Draw the line F G of Fig. 719, in length equal to F G of Fig. 718, and from point G erect a perpendicular, in length equal to G S of Fig. 718. Connect F S, which gives the distance between points F and S. For the second section draw *v o*, in length equal to *v o* of Fig. 718,

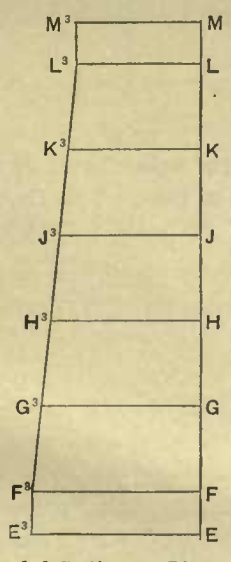


Fig. 717.—Extended Section on Line c m of Fig. 714.

and make the perpendiculars *o* 6 and *v* 7 of the section equal to lines having similar letters in Fig. 718. The other sections are obtained in a similar manner. To construct the sections represented by dotted lines in Fig. 718, proceed as follows: Draw the line F *o* of Fig. 720, in length equal to F *o* of Fig. 718, and from *o* erect the perpendicular *o* 6, equal to *o* 6 of Fig. 718, and connect F 6. For the second section draw *v p*, in length equal to *v p* of Fig. 718, and from points *v* and *p* erect perpendiculars equal to *v* 7 and *p* 5 of Fig. 718. Connect points 7 5, which give the distance between corresponding points in Fig. 718.

In Fig. 721, G G′ F′ F is the pattern of part of

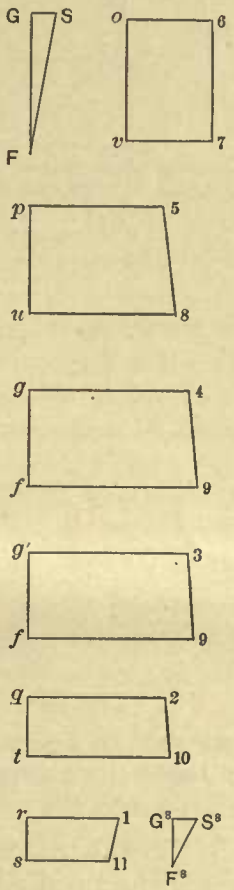


Fig. 719.—Sections on Solid Lines of Fig. 718.

artiele shown by similar letters in Figs. 714 or 718. The distances represented by solid lines in pattern are obtained from the sections in Fig. 719, as indicated by corresponding figures, and the distances represented by dotted lines in pattern are obtained from the sections in Fig. 720. The stretchout of G G′ of the pattern is obtained from G T T′ G′ of Fig. 718, as the stretchout of F U F′ of the pattern is obtained from F U F′ of Fig. 718.

To develop the pattern from the sections above constructed, first draw G F of Fig. 721, in length equal to G F of Fig. 718 or 719, upon which duplicate the

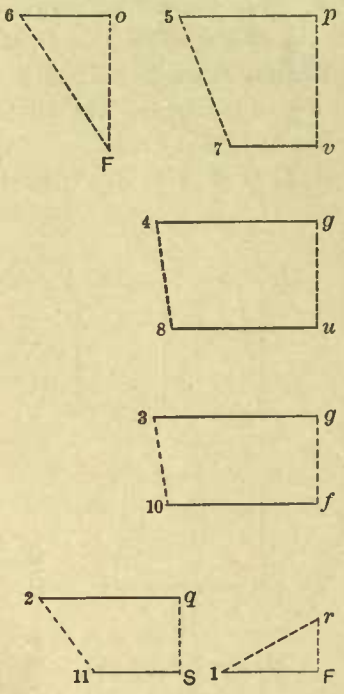


Fig. 720.—Sections on Dotted Lines of Fig. 718.

triangle G F S of Fig. 719, as shown. From S of pattern as center, with S 6 of Fig. 718 as radius, describe an arc, 6, which intersect with one struck from F of pattern as center, with radius F 6 of Fig. 720, thus establishing point 6 of pattern. Then with radius F 7 of Fig. 718, from F of pattern as center, describe an arc, which intersect with a second arc struck from point 6 of pattern as center, and 6 7 of Fig. 719 as radius, thus establishing point 7 of pattern. Continue this process until the various points indicated in pattern are located. Lines drawn through the points

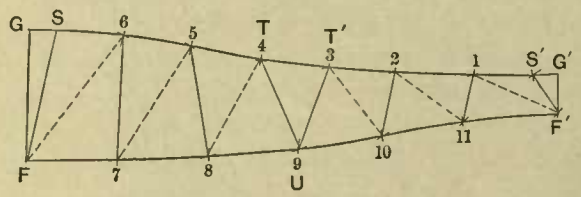


Fig. 721.—Half Pattern of F G G′ F′ of Fig. 714.

thus obtained, as indicated by G S T T′ S′ G′ and F′ U F, will complete one-half of the required pattern. The other half can be obtained by duplication or by a repetition of the above process.

In obtaining the pattern for any one of the remaining pieces first draw a duplicate of its elevation as taken from Fig. 714, upon either side of which construct the proper section, obtaining the points in the same from Figs. 715, 716 and 717 as was done in Fig. 718, after which the subsequent operation is analagous to that above described.

PROBLEM 214.

Pattern for the Soffit of a Semicircular Arch in a Circular Wall, the Soffit Being Level at the Top and the Jambs of the Opening Being at Right Angles to the Walls in Plan. Two Cases.

First Case.—In Fig. 722, let A B C represent the outer curve of an arch in a circular wall corresponding to A′ H C′ of plan, and let E B D represent the inner opening in the wall, as shown by E′ F′ D′ in plan. Then A E B C D will represent the soffit of the arch in elevation and A′ H C′ D′ F′ E′ the same in plan. In the engraving the outer curve of the arch is a perfect semicircle, and the inner curve is stilted, as shown, so as to make the soffit level at B. Instead of the stilted arch, the inner curve may, if desired, be drawn as a semi-ellipse of which E D is the minor axis and F B one-half of the major axis.

Divide A B of elevation into any convenient number of equal parts, shown by the small figures. With the T-square parallel with the center line B B′, drop lines from the points in A B, cutting A′ H of plan, as shown. Since that portion of the inner arch from E to 12 is drawn vertical, as above explained, divide 12 B into the same number of parts as was A B, and, with the T-square parallel with the center line B B′, drop lines to E′ F′, as shown. Connect opposite points in A′ H with those in E′ F′, as shown by the solid lines in plan. Also divide the four-sided figures thus produced by means of the diagonal dotted lines 6 8, 5 9, etc., as shown. The several triangles thus produced will represent in plan the triangles into which the soffit, or under side, of the arch is divided for the purpose of obtaining its pattern. In order to ascer-

tain the real distances across the surface of the arch which the solid and dotted lines represent, it will be necessary to construct a series of sections of which these lines are the bases, as shown in Figs. 723 and 724.

In constructing the diagram shown Fig. 723, the several solid lines of the plan, though not exactly equal in length (because they are not drawn radially from the center of the curve A′ H C′), may be considered as of the same length. Draw the right angle P Q R as in Fig. 723, and from Q set off horizontally the distance H F′ of plan, as shown by Q R. Draw R S parallel with Q P, and, measuring from Q, set off on Q P the length of lines dropped from points in A

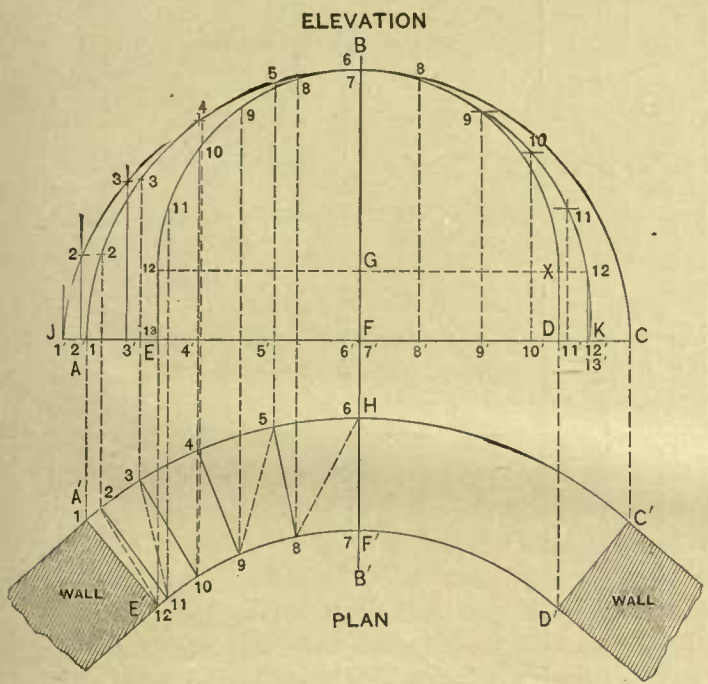


Fig. 722.—Plan and Elevation of Arch in a Circular Wall.—First Case.

B to A F, as shown by corresponding figures 2 to 6. Likewise set off from R on R S the length of lines dropped from points in E B to E F, as shown by the figures 12 to 7, and connect the points in P Q with those in S R, as indicated by the solid lines in plan. Thus connect 1 with 12, 2 with 11, 3 with 10, etc. To construct the diagram based upon the dotted lines of the plan, draw the right angle M N O in Fig. 724, and, measuring in each instance from N, set off on N M the same distances as in Q P of Fig. 723. Starting from N, set off on N O the lengths of dotted lines in plan, as shown by the small figures in N O. With the T-square parallel with M N, draw lines from the points in N O, and, in each instance measuring from N O, make these lines of the same length as lines of similar number dropped from points in E B of elevation to E F. Connect the points in these lines with points in M N, as indicated in plan by the dotted

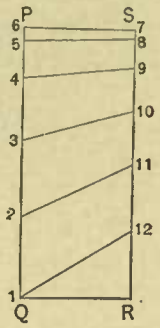


Fig. 723.—Diagram of Sections on Solid Lines of Plan, Fig. 722.

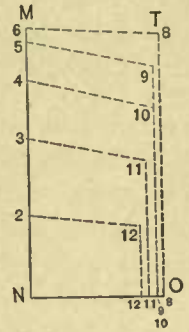


Fig. 724.—Diagram of Sections on Dotted Lines of Plan, Fig. 722.

lines. Thus connect 6 with 8, 5 with 9, 4 with 10, etc.

The next step is to obtain the distances between points in A B of elevation as if measured on the outer opening in the curved wall. To do this, on F A extended set off a stretchout of A′ H of plan, as shown by the small figures 5′, 4′, etc., and with the T-square at right angles to the stretchout line J F, draw the usual measuring lines. With the T-square parallel with J F, carry lines from the points in A B to lines of similar number drawn from the stretchout line. A line traced through these points, as shown by J B, will give the true distances desired between the points in the outer curve of the arch.

The distances between points in E B, the inner curve, are obtained in a similar manner. To avoid a confusion of lines, the stretchout of F′ E′ of plan is

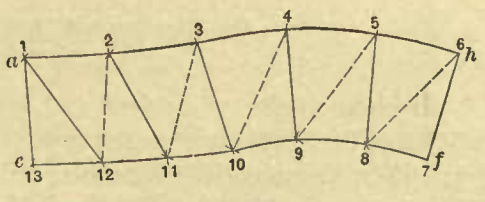


Fig. 725.—One-Half Pattern of Soffit of Arch Shown in Fig. 722.

set off on F C of elevation, as shown by the small figures, 7′, 8′, 9′, etc. B D is also divided into the same parts as was E B, and from the points thus obtained lines are drawn to the right parallel with F C. With the T-square parallel with B F, carry lines

from the stretchout points in F K, cutting lines of similar number drawn from the points in B D. A line traced through the points thus obtained, as shown by B K, will give the distance between points as if measured on the inner curved line of the wall.

From the several sections now obtained the pattern may be developed in the following manner: At any convenient place draw the line *a e* in Fig. 725, making it in length equal to Q R of Fig. 723, or A′ E′ thus establishing the point 11 of pattern. Continue in this way, using the tops of the sections in Figs. 723 and 724 for measurements across the pattern, the spaces in J B for the distances along the edge *a h* of pattern, and the spaces in B K for the distances along the inner edge *e f*, establishing the several points, as shown. Through the points in *a h* and *e f* lines are to be traced, while *f h* is to be connected by a straight line, thus completing one-half the pattern. The other

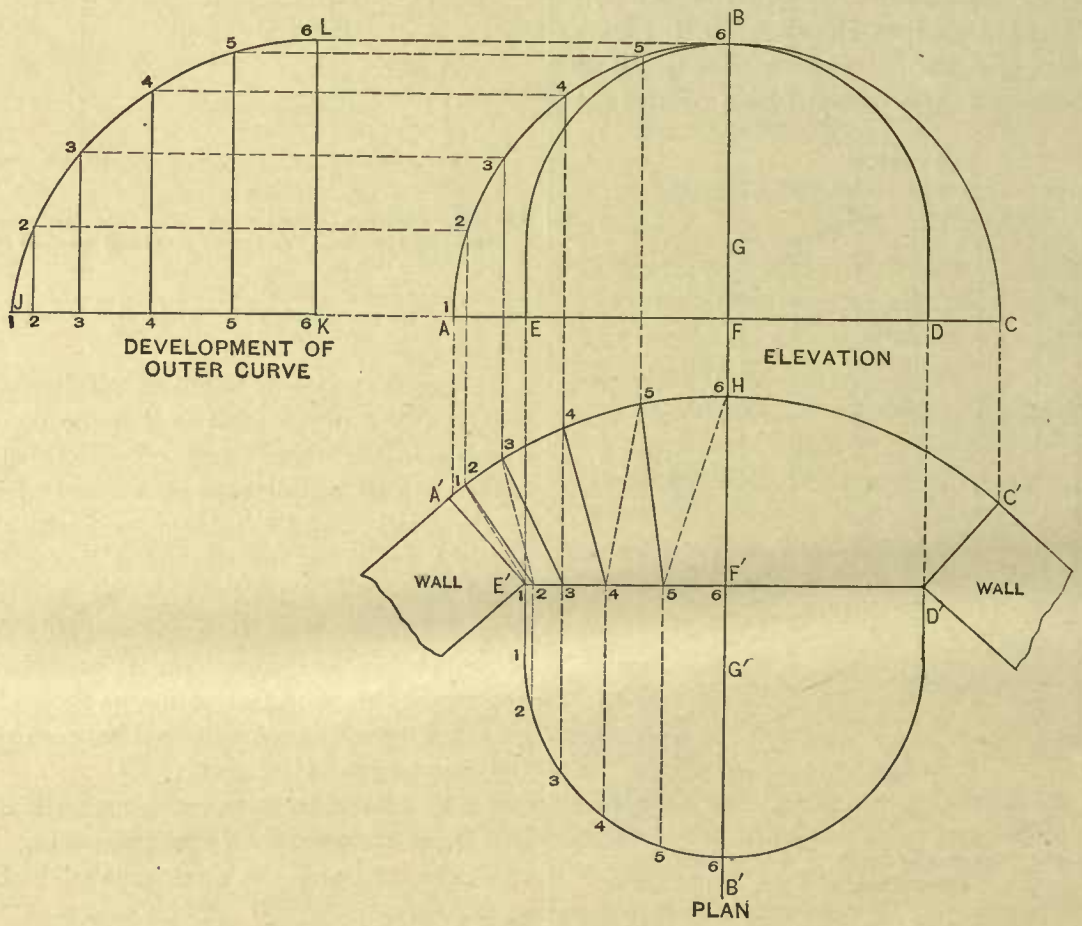


Fig. 726.—Plan and Elevation of Arch in a Circular Wall.—Second Case.

of plan. At right angles to *a e* draw *e* 12, in length equal to R 12 of Fig. 723, and connect *a* with 12 if it is desired to show the triangle. From *a* as center, and J 2 of elevation as radius, describe a small arc, 2, which intersect with one struck from point 12 of pattern as center, and 12 2 of Fig. 724 as radius, thus establishing the point 2 of pattern. With 2 of pattern as center, and 2 11 of Fig. 723 as radius, describe another arc, 11, which intersect with one struck from 12 of pattern as center, and 12 11 of B K as radius, half of pattern can be obtained by the same method or by any convenient means of duplication.

If the arch were semi-elliptical instead of semi-circular, the method of procedure would be the same as above described.

Second Case.—In Fig. 726, A B C represents the outer curve of an arch in circular wall, as shown by A′ H C′ in plan. E B D represents the inner curve in elevation, as does E′ D′ the same in plan. Then A E B D C represents the soffit of the arch in eleva-

tion and A′ H C′ D′ E′ the same in plan. The conditions given in this case differ from those of the first case only in the fact that the inner curve of the arch in this case is straight in plan, as shown by E′ D′, instead of curved to the radius of the wall as in Fig. 722. The method of procedure in this case is exactly the same as before, but one less operation will be necessary, since measurements upon the inner curve may be taken directly from E B D of the elevation.

To avoid a confusion of lines, a duplicate

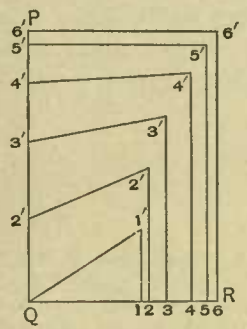


Fig. 727.—Diagram of Sections on Solid Lines of Plan, Fig. 726.

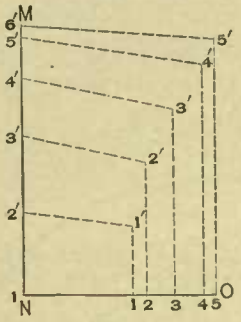


Fig. 728.—Diagram of Sections on Dotted Lines of Plan, Fig. 726.

of E B D of elevation has been drawn in plan, as shown by E′ B′ D′. To obtain the divisions on plan divide A B into any convenient number of equal parts, and from the points thus obtained drop lines parallel with the center line B B′ to A′ H of plan, as shown. Divide E′ B′ in a similar manner, and from the points thus obtained drop lines to E′ F′ of the plan, as shown. Connect points in A′ H′ with those of similar number in E′ F′ by solid lines. Also connect points in A′ H with those of next lower number in E′ F′ by dotted lines. These solid and dotted lines just drawn will form the bases of a series of sections, shown in Figs. 727 and 728, whose upper lines will give correct distances across the pattern of the soffit.

To construct the sections based upon the solid lines of the plan, first draw the right angle P Q R in Fig. 727, and set off on Q P, measuring from Q, the length of the vertical lines in A B F of elevation. Starting from Q, set off on Q R the length of solid lines in A′ H F′ E′ of plan, as shown by the small figures in Q R. With the T-square parallel with P Q, draw lines from the points in Q R, and, measuring from Q R, set off on these lines the length of lines of corresponding number in E′ F′ B′ of plan, and connect the points with points of similar number in P Q. The diagram of sections based upon the dotted lines of the plan, shown in Fig. 728, is constructed in the same manner, using the length of dotted lines in plan for the distances in N O, the length of lines in E′ F′ B′ of plan for the length of lines set off at right angles to N O, and the length of lines in A B F of elevation for the distances in M N. Connect the points as indicated by the dotted lines of the plan, all as shown.

The next step is to obtain the correct distances between points in A B of elevation, or A′ H of plan. To do this lay off horizontally J K, on which set off a stretchout of A′ H of plan, and, with the T-square at right angles with J K, draw the usual measuring lines. With the T-square parallel with J K, carry lines from the points in A B to lines of similar number. A line can be traced through these points, as shown by J L, from which the correct stretchout of the outer side of the pattern can be obtained.

To describe the pattern first draw any line, as *a e* of Fig. 729, equal to A′ E′ of plan. With *e* of pattern as center, and E′ 1 of the inner curve of the arch as radius, strike a small arc, 1′, which intersect with one struck from *a* of pattern as center, and Q 1′ of Fig. 727 as radius, thus establishing the point 1′ of pattern. With *a* of pattern as center, and J 2 of Fig. 726 as radius, describe a small arc, 2, which intersect with one struck from 1′ of pattern as center, and 1′ 2′ of Fig. 728 as radius, thus establishing point 2 of pattern. Then from 2 as center, with 2′ 2′ of Fig. 727 as radius, strike a small arc, 2′, which is inter-

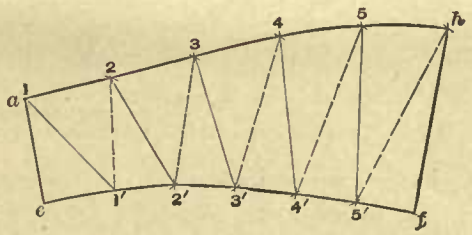


Fig. 729.—Half Pattern of Soffit Shown in Fig. 726.

sected with one struck from 1′ of pattern as center, and 1 2 of the inner curve of the arch as radius, thus definitely establishing the point 2′ of pattern. Continue in this way, using the tops of sections in Figs. 727 and 728 for measurements across the pattern, and the spaces in the inner curve E′ B′ and in outer curve as developed in J L, Fig. 726, for the distances about the edges of the pattern, establishing the several points, as shown. Connect points *h* and *f* with a straight line, and through the intermediate points trace the curves, as shown. The other half of pattern can be obtained by the same method or by duplication.

PROBLEM 215.

Pattern for a Splayed Elliptical Arch in a Circular Wall, the Opening Being Larger on the Outside of the Wall than on the Inside.

In Fig. 730 is shown the elevation and plan of an elliptical window head in a circular wall. The outer curve of head is represented by A B C in elevation and by A′ B′ C′ in plan. The inner curve is represented by F E D in elevation and F′ E′ D′ in plan. A B C D E F therefore represents the splayed or beveled portion in elevation for which the pattern is required, and A′ B′ C′ D′ E′ F′ the plan of the same. Divide A B of elevation into any convenient number of parts, in the present instance five. For convenience number the points thus obtained, as shown by the small figures. Drop perpendiculars from the points in A B, cutting A′ B′ of plan, as shown. Also divide F E of elevation into the same number of parts as was A B, and drop similar perpendiculars to F′ E′ of plan. Connect opposite points in A′ B′ with those in F′ E′, as shown by the solid lines, as 2 11, 3 10, etc. Also divide the four-sided figures thus produced into triangles by means of the dotted lines, as shown from 1 to 11, 2 to 10, etc. To ascertain the true distances across the face of the arch which these several solid and dotted lines of the plan represent, it will be necessary to construct vertical sections through the arch upon each one of these lines as a base. The lines dropped from A B to A G of elevation give the hight of sections on A′ B′ of plan, as the lines dropped from F E to F G give the hight of sections on F′ E′ of plan.

To construct the sections shown in Fig. 731, represented in plan by the solid lines, proceed as follows: Draw the right angle *a a′* 1, making *a a′* equal to E′ B′ of plan, and *a′* 1 equal to G B (*a* 1) of elevation. Draw *a* 12 parallel to *a′* 1, making its length equal to G E (*a* 12) of elevation, and connect 12 with 1. The distance 12 1 of this section represents the actual distance between the points 1 and 12 in the elevation or plan. The second section is constructed in a similar manner; *b c* represents the distance 2 11 of plan; *b′* 11 is equal to *b* 11 of elevation and *c* 2 to *c* 2 of elevation. Connect 11 with 2 of section, which will give the actual distance between points 11 and 2 of elevation or plan. The remaining sections are constructed in a similar manner, each of the sections representing a vertical section through the head on the lines of corresponding numbers in the plan. The sections based upon the dotted lines of the plan, shown in Fig. 732, are constructed in exactly the same manner. Draw *b a*, in length equal to 1 11 of plan, and erect the two perpendiculars, as shown. Make *a* 1 of section equal to *a* 1 of elevation, and also make *b* 11 of section equal to *b*

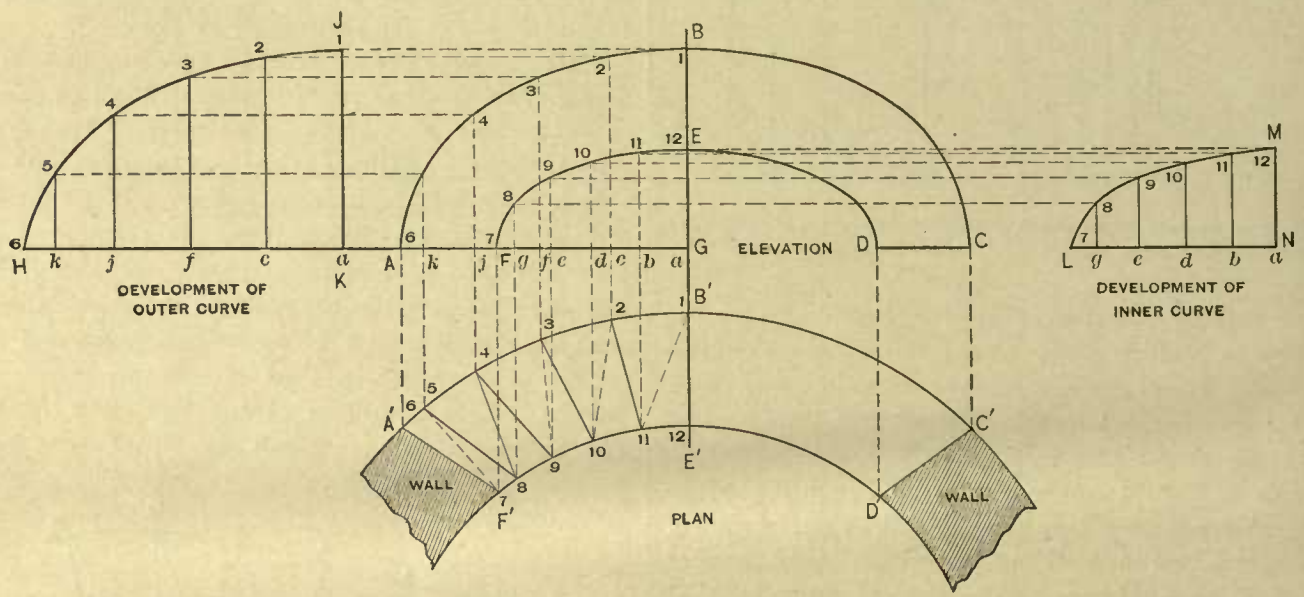


Fig. 730.—Elevation and Plan of Splayed Elliptical Arch.

11 of elevation, and connect 11 with 1. The remaining sections are constructed in the same manner.

Before the pattern can be obtained it will be necessary to develop extended sections of the inner and

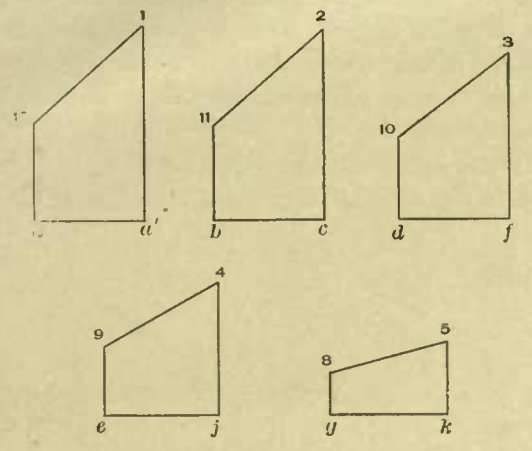


Fig. 731.—Sections Based Upon the Solid Lines of the Plan, Fig. 730.

outer curves, as shown to the left and right of the elevation. This is done for the purpose of obtaining the actual distance between points shown in elevation. For convenience, on G A extended, as H K, lay off a stretchout of A′ B′ of plan, and from the points therein contained erect the perpendiculars, as shown. From the points in A B of elevation draw lines parallel with H G, cutting perpendiculars of similar number erected from H K. A line drawn through these points of in-

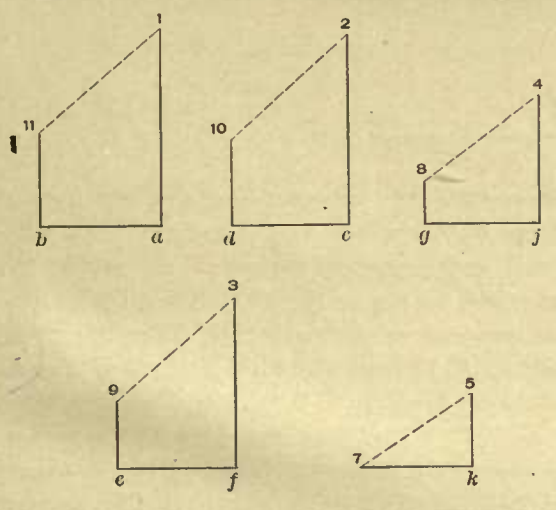


Fig. 732.—Sections Based Upon the Dotted Lines of the Plan, Fig. 730.

tersection, as shown by H J, will show the shape of A B of elevation as laid out on a flat surface. The development of the inner curve is shown to the right of the elevation. On L N is laid out the stretchout of F′ E′ of plan, and on the perpendiculars erected from the points in the line are set off the same distances as on lines of similar number in F E G of elevation. A line traced through these points, as shown by L M, also shows the shape of F E, as laid out on a flat surface, and gives the distance between points as if measured on the finished article.

To obtain the pattern, using the distances between points in H J and L M of Fig. 730, and the diagrams in Figs. 731 and 732, proceed as follows: Draw any line, as B E in Fig. 733, in length equal to 1 12 of the first section in Fig. 731. With E as center, and M 11 of inner curve as radius, describe a small arc, 11, which intersect with one struck from B as center, and 1 11 of Fig. 732 as radius, thus establishing the point 11 of pattern. With 11 of pattern as center, and 11 2 of the second section in Fig. 731 as radius, describe an-

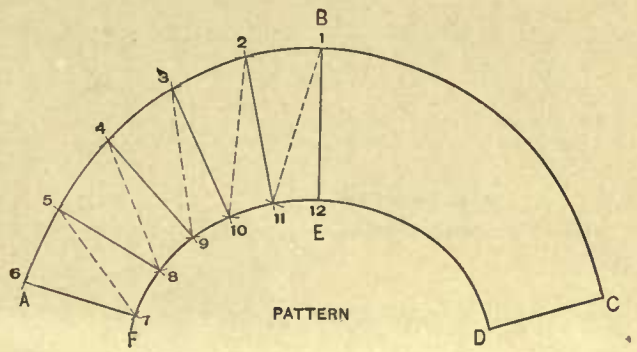


Fig. 733.—Pattern of Splayed Arch in Fig. 730.

other small arc, 2, which intersect with one struck from point B of pattern as center, and J 2 in J H of outer curve as radius, thus establishing the point 2 of pattern. Continue in this way, using the tops of the sections in Figs. 731 and 732 for the measurements across the pattern, the spaces in the inner curve L M and in the outer curve H J for the distances about the edges of the pattern, establishing the several points, through which draw the lines shown. Then B A F E is the half pattern of splayed head, shown in elevation by A B E F. The other half can be obtained by any convenient means of duplication.

A semicircular splayed arch can be developed in the same manner as above described.

The pattern for a blank for a curved molding, either semicircular or semi-elliptical, for an arch in a circular wall comprises really the same relations of parts as are shown in Fig. 730, and could be obtained as above described.

PROBLEM 216.

Pattern for a Splayed Arch in a Circular Wall, the Larger Opening Being on the Inside of the Wall.

In Fig. 734 is shown the plan and elevation of an arch in a curved wall, such as might be used as the head of a window or door, the jambs and head to have the same splay. In the plan, C E D represents the inner curve of wall and A F B the outer. J G M in elevation represents the inner curve and K H L the outer. In order to arrive at a system of triangles by means of which to measure the splayed surface, first divide J G of the elevation into any convenient number of parts, in this case five, as indicated by the small figures. From the points in the curve thus established drop lines parallel to the center line G F, cutting the inner curve of the plan C E, as shown. Next carry lines from points in J G in the direction of the center X, intersecting the outer curve and establishing the points 7, 8, 9, etc., in it. From these points drop lines to the outer curve in plan A F, establishing the points 7, 8, 9, etc. Connect opposite points in J G with those in K H, as 1 and 7, 2 and 8, 3 and 9, 4 and 10, 5 and 11, and 6 and 12. Likewise connect 1 and 8, 2 and 9, 3 and 10, etc., as shown by the dotted lines. In the same manner connect corresponding points in the inner and outer lines of plan, as shown. The solid and dotted lines of the plan will form the bases of a series of right angled triangles whose altitudes can be found in the elevation, and whose hypothenuses will give correct measurements across the face of the splayed surface.

To determine the hights of these triangles extend to the left the horizontal lines drawn through K H of the elevation until they intersect lines dropped from J G, as shown by the points *b*, *d*, *f* and *h*. Then *b* 2, *d* 3, etc., will be the required hights. To construct the triangles which represent the solid lines in plan and elevation, proceed as shown in Fig. 735: For the first triangle, G H 7, draw the right angle G H 7, making the altitude equal to G H of elevation and the base equal to E F, 1 7, of plan, and draw the hypothenuse, which represents the actual distance between the points 1 and 7 of the elevation or plan. In like manner the hypothenuse of the second triangle 2 *b* 8 shows the actual distance between the points 2 and 8 of the elevation; 2 *b* in Fig. 735 is made equal to 2 *b* of the elevation, while *b* 8 equals 2 8 of the plan.

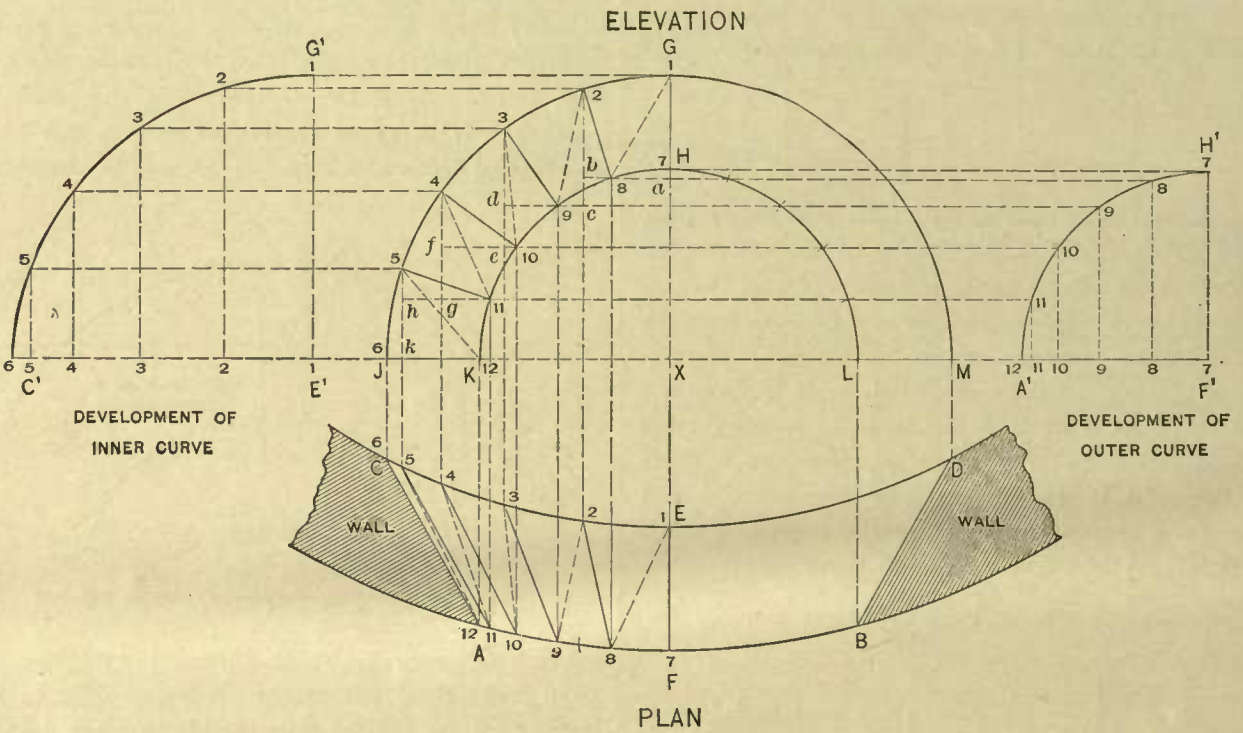


Fig. 734.—Plan, Elevation and Extended Sections of Splayed Arch.

The remaining triangles in Fig. 735 are constructed in a similar manner, each of the triangles representing a vertical section through the head on the lines of corresponding numbers in the plan.

The triangles shown in Fig. 736 correspond to similar sections taken on the dotted lines in plan. The base *a* 8 of the first triangle is equal to 1 8 of the plan, and the hight 1 *a* to 1 *a* of elevation, the point *a* of the elevation being on a level with 8, as shown by the dotted line 8 *a*. The hypothenuse 1 8 is then drawn, which gives the distance between the points 1

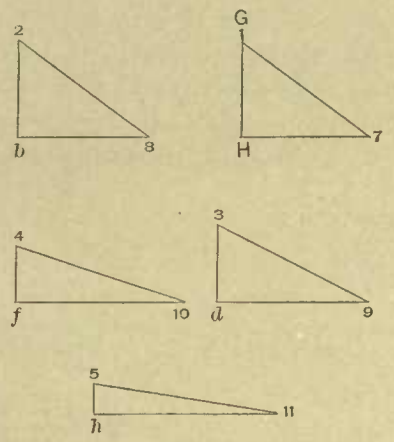


Fig. 735.—Diagram of Triangles Based Upon the Sotid Lines of the Plan.

and 8 in plan or elevation. The bases of the remaining triangles are derived from the dotted lines in plan, and the hights from the distances 2 *c*, 3 *e*, 4 *g* and 5 *k* of elevation.

Before the correct measurements or stretchouts for the inner and outer lines of the pattern can be obtained it will be necessary to develop extended sections of the inner and outer curves of the arch in elevation, as shown at the left and right of that view. For the development of the outer curve, as shown to the right by A′ H′ F′, proceed as follows: On X M extended lay off a stretchout equal to A F of the plan, transferring it point by point. From the points thus established in A′ F′ carry lines vertically, extending them indefinitely, as shown, and then from the points in the outer curve K H of the elevation carry lines horizontally to the right, intersecting the corresponding lines just drawn from A′ F′, and through the points thus established trace the curved line A′ H′. The development of inner curve, as shown to the left, is accomplished in a similar manner. On X J extended lay off a stretchout of C E of plan, and from the points thus established carry lines vertically. From the points in the inner curve J G carry lines horizontally to the left, intersecting lines of similar number, and through the points thus established trace the curve C′ G′.

To describe the pattern shown in Fig. 737, first

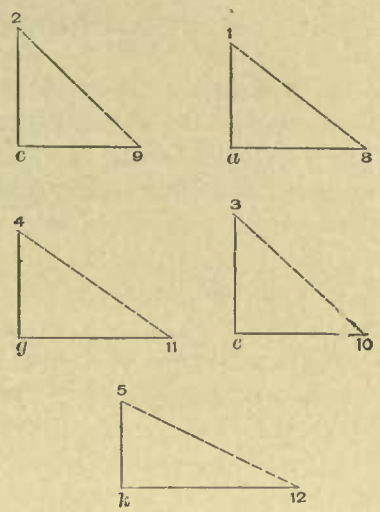


Fig. 736.—Diagram of Triangles Based Upon the Dotted Lines of the Plan.

draw the line *g h*, or 1 7, in length equal to the hypothenuse 1 7 of the first triangle in Fig. 735. From 7 as center, with 7 8 of the development of the outer curve as radius, strike a small arc, as shown at 8 in the pattern. From 1 as center, with 1 8 of the first triangle in Fig.

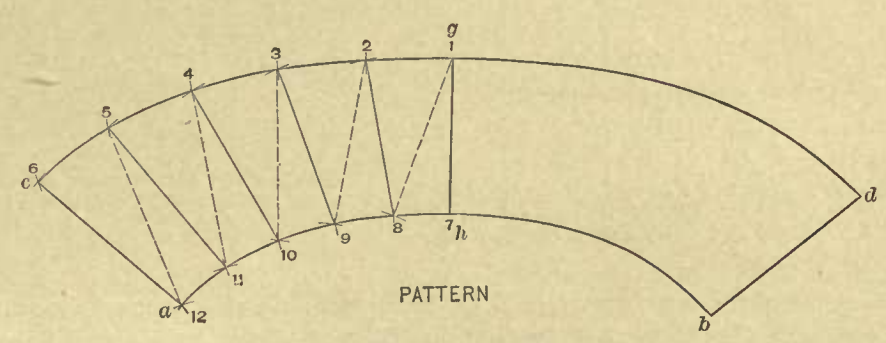


Fig. 737.—Pattern for Splayed Arch.

736 as radius, intersect the arc last struck, thus establishing the point 8. From 1 as center, with radius equal to 1 2 of the development of inner curve, strike a small arc, as shown at 2. Then from 8 as center, with 8 2 of the second triangle in Fig. 735 as radius,

intersect the are at 2 already drawn, thus definitely establishing the point 2 in the upper line of the pattern. Continue in this way, using the hypothenuses of the several triangles, as shown, for measurements across the pattern, and the spaces of the inner and outer curves as developed in Fig. 734 for the distanees along the edges of the pattern, establishing the several points, as shown. Lines traeed through the points from *c* to *g* and from *a* to *h* will complete the pattern for one-half the arch. The complete pattern is shown in Fig. 737.

PROBLEM 217.

Pattern for the Soffit of an Arch in a Circular Wall, the Soffit Being Level at the Top and the Jambs of the Opening Being Splayed on the Inside.

In Fig. 738, A B C is the elevation of the inner curve A′ H C′ of the plan and E B D that of the outer curve E′ F′ D′. As will be seen by inspection, the outer curve is drawn from G as center, that portion of the opening from the springing line down to the springing line of the inner curve, as E 12, being straight and vertical. The pattern of the soffit could have been obtained in exactly the same manner had the elevation of this outer curve been a semi-ellipse.

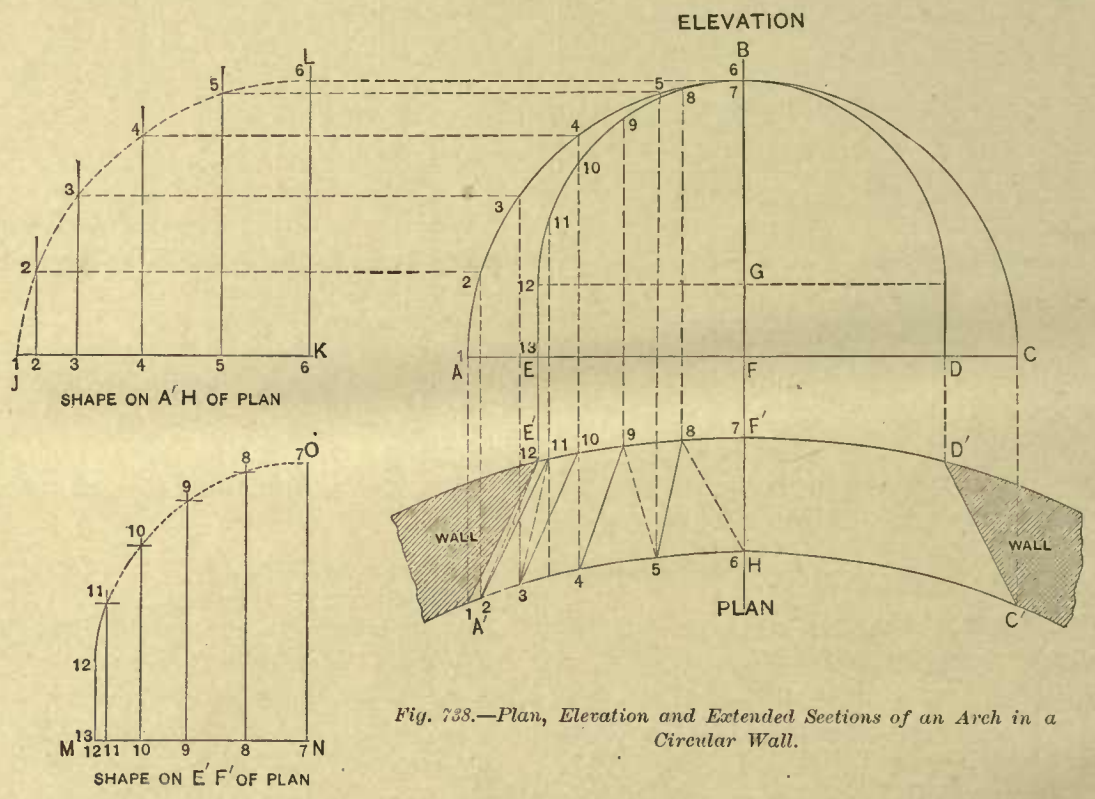


Fig. 738.—Plan, Elevation and Extended Sections of an Arch in a Circular Wall.

Divide A B of the elevation line into any convenient number of equal parts, and with the T-square parallel with center line B H drop lines from the points in A B, cutting A′ H of plan, as shown by the small figures 1 to 6. As the semicircle representing the outer curve of wall is struck from G as center, divide 12 B into the same number of parts as was A B, and drop lines from these points to E′ F′ of plan, as shown. Connect opposite points in E′ F′ of plan with those in A′ H, as indicated by the solid lines. Also connect the points of the plan obliquely, as shown by the dotted lines, thus dividing the plan of the soffit of the arch into triangles. In order to ascertain the true distanees which these lines drawn across the plan represent it will be necessary to construct a series of sections of which they are the bases, as shown in Figs. 739 and 740.

In Fig. 739 is shown a diagram of sections corresponding to the solid lines in plan, to construct which

proceed as follows: Draw the right angle P Q R, and, measuring from Q, set off on Q P the length of lines dropped from points in A B of elevation to A F, as shown by the figures 2 to 6. Likewise set off from Q on Q R the length of solid lines in plan, as shown by the small figures 7 to 12. With the T-square parallel with P Q, erect lines from the points in Q R, and, measuring from Q R, set off on these lines the length of lines of corresponding number in E B F of elevation,

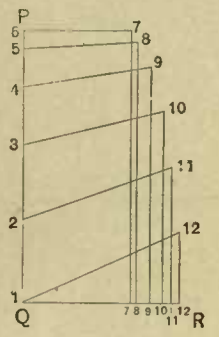


Fig. 739.—Diagram of Sections on the Solid Lines of the Plan.

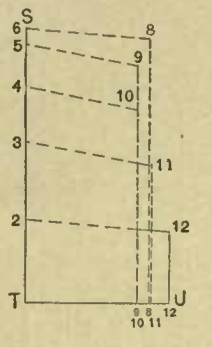


Fig. 740.—Diagram of Sections on the Dotted Lines of the Plan.

and connect the points thus obtained with the points in P Q, as indicated by the numbers in the plan. Thus connect 6 with 7, 5 with 8, 4 with 9, etc.

To construct a diagram of sections corresponding to the dotted lines of the plan draw the right angle S T U, Fig. 740, and set off on S T the length of lines dropped from points in A B of elevation to A F, or tranfer the distances in P Q, Fig. 739. On T U set off the length of dotted lines in plan, and from the points thus obtained draw lines parallel with S T, making these lines of the same length as those dropped from points in E B of elevation to E F. Connect the upper ends of lines 8 to 12 with points in S T, as indicated by the dotted lines in plan. Thus connect 2 with 12, 3 with 11, 4 with 10, etc.

The next step is to obtain the distance between points in A B and E B of elevation as if measured upon the curved surfaces of the wall. It is therefore necessary to develop extended sections of the two curves of the arch as shown at the left in the engraving. The development of the curve of the inner side of the arch is projected directly from the elevation in the following manner: On A F extended lay off J K, equal to the curved line A′ H of plan, making the straight line equal to the stretchout of half of the curve of the plan, as indicated by the small figures. At right angles to J K, and from the points in the same, erect lines, making them the same length as lines of similar number dropped from points in A B, or, with the T-square parallel with J K and A F, carry lines from the points in A B intersecting the vertical lines of similar number. A line traced through the points of intersection, as shown by J L, will be the desired shape. The shape on E′ F′ of the plan, corresponding to E B F of elevation, is obtained in a similar manner. On M N in Fig. 738 set off the stretchout of E′ F′ of plan, as indicated by the small figures, from the points of which erect vertical lines. On these lines set off the same length as the lines of similar number in E B F of elevation. A line traced through the points thus obtained will give the desired outer curve of the arch.

To develop the pattern from the several sections obtained proceed in the following manner: Draw the line *a e* of Fig. 741, in length equal to Q R of Fig. 739, and with *e* as center, and M 12 of the curve M O as radius, strike a small arc, 12, which intersect with one struck from *a* as center, and Q 12 of Fig. 739 as radius, thus establishing the point 12 of pattern. With *a* of pattern as center, and J 2 in the curve J L as radius, describe a small arc, 2, which intersect with one struck from point 12 of pattern as center, and 2 12 of Fig. 740 as radius, thus establishing the point 2 of pattern. With 2 of pattern as center, and 2 11 of Fig. 739 as radius, strike another small arc, which intersect with one struck from point 12 of pattern as center, and 12 11 in the curve M O as radius, thus establishing the point 11 of pattern. Continue in this way, using the tops of the sections in Figs. 739 and

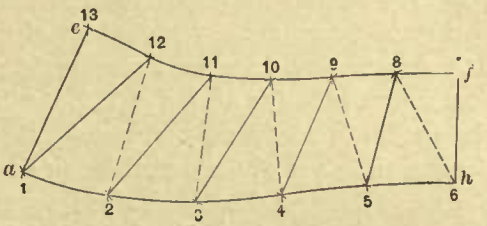


Fig. 741.—Half Pattern of Soffit.

740 for measurements across the pattern, and the spaces in the inner and outer curves as developed in J L and M O, Fig. 738, for the distances about the edges of the pattern, establishing the several points, as shown, through which draw the lines *e f*, *a h* and *f h*, thus completing the pattern for one-half the soffit of the arch. The other half of pattern can be obtained by the same method or by duplication.

PROBLEM 218.

Pattern of the Blank for a Curved Molding in an Arch in a Circular Wall.

In the last paragraph of Problem 215 it is stated that the demonstration there given is applicable to the blank for a curved molding in a circular wall. There are many forms of arches and different methods of adapting them to the requirements of a curved wall. An arch may be semicircular or elliptical, having either the long or the short diameter of the ellipse as its width; and in either case it may be rampant, though rampant arches are seldom used. Any form of arch may be so constructed that its moldings project either from the exterior or from the interior surface of a curved wall. In adapting any form of arch to a circular wall the soffits and roof strip, or portions which appear level at the top of the arch, may, as they are carried around the curve of the arch, arrive at the springing line or top of the impost parallel to the center line in plan; or they may at this point be drawn radially to the curve of the wall.

In Fig. 742 is shown one-half of the elevation and plan of a semicircular window cap and a section on the center line of the same. M K L N is one-half the elevation of all the members constituting the molding, the lines of which are projected from the profile W as shown to the right of the center line. In the plan, those lines which in profile W were drawn horizontally are here drawn parallel to the center line B G. They might with equal propriety have been drawn radially toward the center of the curve E C. Should they be drawn radially the profile of the molding would remain nearly normal throughout its course, but when drawn as in the plan, Fig. 742, it will be seen that the profile is continually changing, that at the foot of the arch or top of the corbel being shown at Y in the plan. This profile is obtained by the usual operation of raking, as shown by the dotted lines.

As the blank for any curved molding is, to the pattern cutter, a flaring strip of metal, it simply becomes necessary to determine its width and the amount of flare which it may assume in the different parts of its course, after which its pattern may be arrived at by methods described in Problem 214 and those following. The direction of the line determining the amount of flare necessary for the strip to have is determined by the judgment of the pattern cutter and the requirements of the machinery used in "raising" the mold. Therefore in making the application of the demonstration given in Problem 215 to the window cap shown in Fig. 742 it is necessary to first draw the lines $k\ g$ of the profile in elevation, and $p\ r$ of the plan, establishing the flare and necessary width or stretchout at those points, after which the points

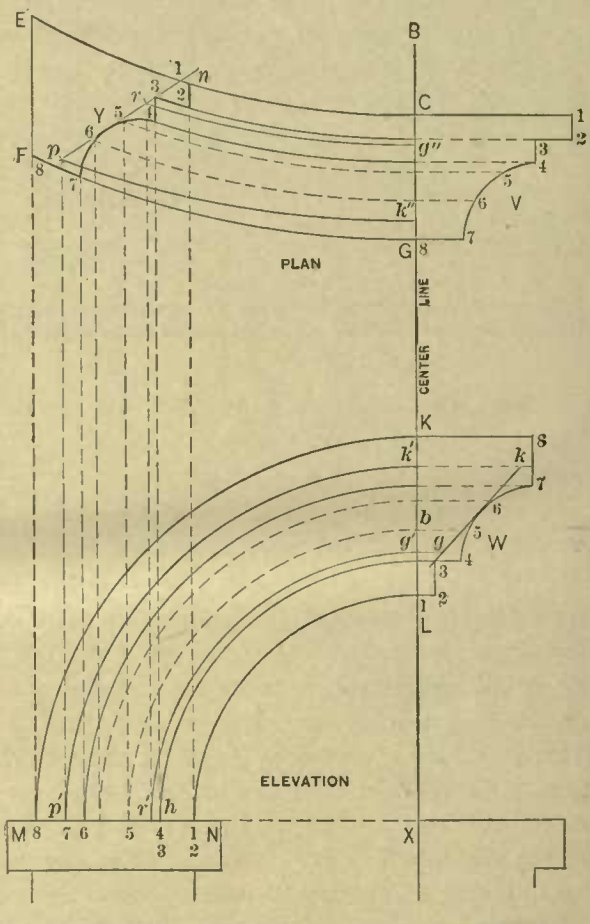


Fig. 742.—Elevation and Plan of an Arched Window Cap in a Circular Wall.

p and r may be dropped upon the line M N of the elevation, and the points k and g carried horizontally to the center line K X, as shown. The points thus obtained in M N and K L must then be connected by the necessary arcs struck from X as center, thus completing an elevation of the flaring piece. Likewise the projection of the points g and k from K L must be set off from C on C G of the plan, as shown at g'' and k'', and the points thus obtained connected with

r and p by ares struck from the center used in deseribing the plan of the wall.

Should the width and flare of the blank, as determined by the raked profile Y at the foot of the arch, vary so much from those of the normal profile at the top that parallel curved lines could not be drawn to connect the points at the foot with those at the top in either or both views, then eenters must be found upon the center lines of the plan and of the elevation from whieh ares ean be drawn connecting the required points. Having thus completed a plan and elevation of the flaring pieee or blank, it will be seen by reference to Problem 215 that the lines p' r' and k' g' of the elevation, Fig. 742, correspond with A F and B E of Fig. 730; and that p r of the plan, Fig. 742, and the ares drawn from it correspond with B′ A′ F′ E′ of Fig. 730; after whieh the demonstration given in that problem may be followed to obtain the required pattern.

It will thus be seen from the foregoing that no matter what form of areh be used or in what manner it be plaeed upon the wall, the method of obtaining the pattern of its flaring surfaces remains the same.

It might under some circumstances be desirable to eonstruct stays at several intervals between the top and the foot of an areh, similar to that shown at Y in Fig. 742, for the purpose of more accurately determining the flare in all parts of its sweep, or for the purpose of constructing a form of templet to assist in the operation of raising the mold. The profiles of such stays ean be obtained by the usual operation of raking, which is fully described in numerous problems in

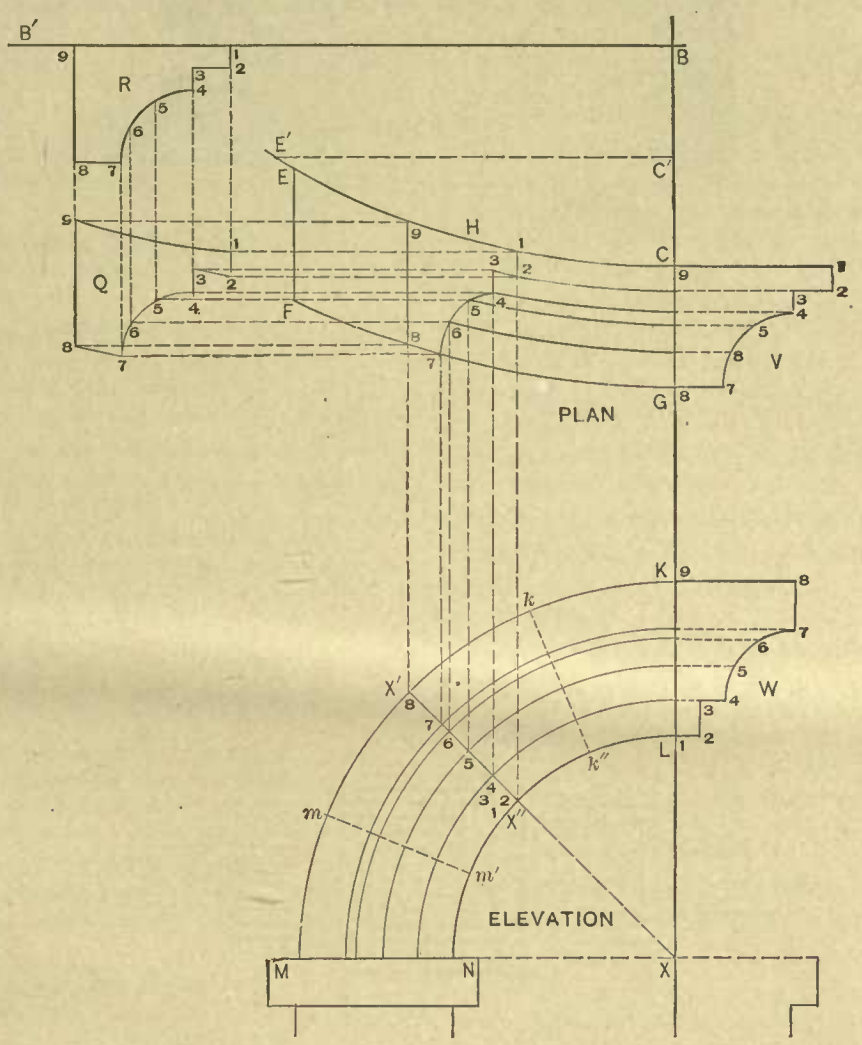


Fig. 743.—Method of Obtaining a Section through Molding.

the first section of this chapter. In Fig. 743 the operation of obtaining a profile upon the line X′ X″ is carried out in all its detail, resulting in the form shown at Q, and needs no further comment.

In constructing a form or templet, as shown in Fig. 744, the outlines of the arch shown in the engraving must be obtained by developing extended sections of those lines on E C of the plan, as described in Problem 214 and those following, after which the stays can be placed upon lines drawn to correspond with those from which the respective sections were taken.

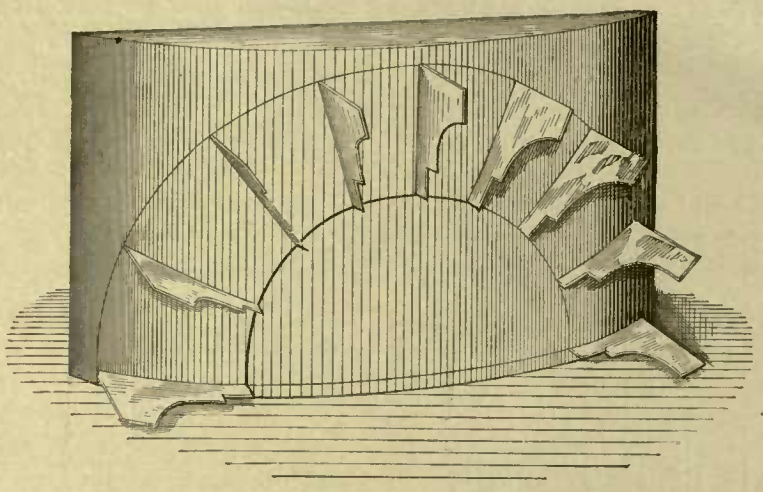
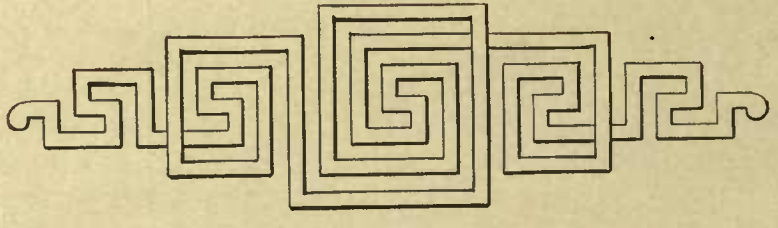


Fig. 744.—Perspective View of Templet for Use in Raising the Curved Mold.



INDEX OF PROBLEMS.

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